PROCEEDINGS OF THE
NATIONAL SYMPOSIUM ON

SHRIMP SEED PRODUCTION AND HATCHERY MANAGEMENT

COCHIN, 21-22, JANUARY 1983

Organised by
The Marine Products Export Development Authority
In association with
Central Marine Fisheries Research Institute, Cochin,
Central Inland Fisheries Research Institute, Barrackpore and
Central Institute of Fisheries Education, Bombay.

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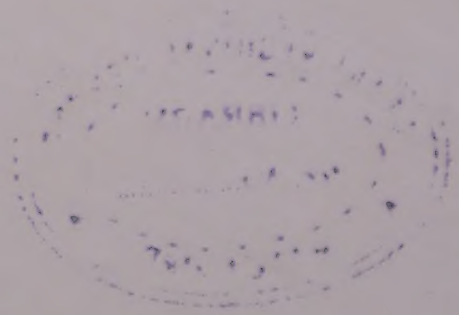

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FOREWORD

The second National Symposium on shrimp farming with the focal theme 'Shrimp seed production and hatchery management' was organised by the Marine Products Export Development Authority in association with CMFRI, CIFRI and CIFE in Cochin during January, 21-22, 1983. This is the first National Symposium completely devoted to shrimp seed production and hatchery management conducted in India. A lead paper in each technical session was presented by an expert in the field, to generate a meaningful discussion. The presentation of poster papers in the field of Fisheries Science was arranged for the first time in India during this symposium.

The great efforts taken by the MPEDA staff and officers particularly Dr. P. U. Verghese, Mr. R. Ganapathy, Dr. G. Santhana Krishnan, Mr A. G. Varghese, Mr. V. Krishnamurthy and Mr. B. Vishnu Bhat in organising the Symposium so successfully are very much appreciated.

This volume containing the lead and poster papers, highlights the current status of shrimp seed production in the country and research so far carried out in this field by the Fisheries Institutes and other agencies. It further draws the attention of the scientific community to improve and evolve a low cost hatchery technology for mass production of prawn larvae. I thank the members of the editorial commitee, for their able editing of the proceedings. The careful compiling and writing of the draft proceedings by Mr. R. Ganapathy and Mr. B. Vishnu Bhat, have greatly helped us in bringing out this volume in a short time.

I am sure, that this volume will generate more interest in the subject presented here and pave the way for further developments in the field.

S. N. RAO
Chairman
MPEDA

Cochin
18-11-'83

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WELCOME ADDRESS

BY

SHRI S. N. RAO

Chairman, M. P. E. D. A.

Mr. President, Hon'ble Minister, Dr. Silas and friends, It is my pleasant duty to extend you all a warm welcome to this "National Symposium on Shrimp Seed Production and Hatchery Management".

First of all, I would like to welcome Prof. Mathew Pylee, worshipful Mayor of Cochin, who has readily agreed to preside over this inaugural function. I also like to extend my warm welcome to Shri Vayalar Ravi, Hon'ble Home Minister, Govt. of Kerala who has kindly agreed to inaugurate this symposium. I would like to welcome Dr. Silas, who doesn't really need any special welcome as he is one among us. I also welcome all the delegates and scientists, who have gathered here in response to our invitation. I also welcome the guests and the Press who are assembled here.

I need not emphasise the importance of this National Symposium. You will agree that the theme which we have selected is a very topical one, especially from the point of view of our organisation, namely, The Marine Products Export Development Authority (MPEDA). As you all are aware, our main constraint in the last few years in boosting export of marine products, has been stagnating fish production, especially that of the shrimp. We have been able to export marine products only to the tune of 70,000 to 75,000 tonnes per annum, out of which the major share has been constituted by shrimp. The only way to increase export is by augmenting the production of shrimp in the country through culture, adopting scientific techniques. The MPEDA, recognising the importance of this programme has recruited a team of scientists and started Regional and Sub Regional Centres at important places in India to develop this sector. We do not believe that by our efforts alone, the anticipated production can be achieved in the near future. It should be the responsibility of the State Governments and also the private sector to take up Shrimp Culture in a big way and see that the target is achieved.

The main constraints in the matter of production by culture is the availability of adequate prawn seed. We have been depending so far on the stock of shrimp seed available from nature. The time has now come to think in terms of setting up modern hatcheries so that we can produce enough material to stock all the prawn farms envisaged for the future. It is in this context that this symposium assumes great importance.

The attendance would have been larger if the topic selected was a general one on "Shrimp production". But we have deliberately restricted the theme to "Shrimp seed production and hatchery management" and perhaps the thin attendance is due to this particular fact. We expect very useful contributions during the discussion. With these few words, I welcome all of you once again to this symposium and I request the President, to conduct the inaugural session.

PRESIDENTIAL ADDRESS

BY
PROF. MATHEW PYLEE
Worshipful Mayor of Cochin

Hon'ble Minister, Mr. Vayalar Ravi, MPEDA Chairman Mr. Rao, Dr. Silas, Ladies and Gentlemen,

Last month I had an opportunity to attend another symposium connected with our marine wealth. It was conducted here under the auspices of Central Institute of Fisheries Technology and that symposium dealt with harvest and post-harvest technology of fish. This symposium, I understand is mainly concerned with the seed production of our leading marine resources i. e., shrimp or prawn. I understand that out of the 75,000 tons of exported marine fishery wealth of India in the year 1981, about 50,000 tonnes were prawns or shrimps. We have so far been gathering prawn or shrimp from wild and this symposium now turns attention of authorities as well as of the People in the particular field into actual production or culture of shrimp which will be greatly helpful for the accumulation of the much needed foreign exchange in a developing country like India. Shrimp or prawn is one of the major items of our exports and it still accounts for over 75% of our exports in fisheries wealth. Apart from the valuable foreign exchange it earns for us, shrimp has recently become a delicacy in the home market as well. Increased shrimp production would augment our food supply, increase rural economy in the home market and provides gainful employment for large number of fishermen and fish farmers and other persons in the coastal regions. As far as Kerala is concerned, being a narrow strip of land, washed by the Arabian sea and dotted with lagoons and backwaters, it offers immense possibility in the field of cultivation of shrimp on commercial basis. By way of a parenthesis, may I say that shrimp is a byway in our country and household article, a delicious food, and a few years back that shrimp had become the theme of a great and popular novel by one of the great literary figures, Shri Thakazhi Sivasankara Pillai. This novel depicted the tie up of sea shore people along the coast to reveal their traditional dangers and venturing into deep sea in frail looking country crafts. This novel inspired for the creation of a film called 'CHEMMEEN' or shrimp which happens to be the first Malayalam film to get the President's Gold Medal.

In fisheries, despite of our vast experience we have so far been only gatherers of shrimp and not growers. Unless there is a perennial source of supply (which depends on proper guiding) on a large scale we are likely to exhaust supply at its very source. Shrimp industry in a way faced very many challenges as faced by the Cashew industries in Kerala. Cashew industry in Kerala mainly depends on its supply from African countries. The cashew that was imported

to India was increasingly in demand and without adequate supply of cashew nuts our industry is more dead than alive. This awareness, in the part of those concerned here with the development of marine fisheries utilisation has helped to focus their attention on shrimp seed production, a novel idea in the development of culture fisheries for prawns. The various Marine Authorities are exploring the ways and means of putting this idea into productive lines. The practice suggested now is to allow shrimp that occur in their locality to nurture and mature and collect the same through various devices. The need for foreign exchange and the prosperity envisaged have caught the imagination of the people and they are now looking forward to cultivation of prawns or shrimps on a much larger scale.

The declaration by the Govt. of India of an Exclusive Economic zone in the open seas for 200 nautical miles covering 2 million square Kilometers provide vast opportunities for fishing and farming in a big way. Assets of individual fisherman or the fishing industry as such without the application of scientific methods of cultivation or expert advise will not deliver the goods. Fortunately the MPEDA and similar other institutions are willing to guide and co-ordinate the activities of fishery industrial units.

Prawns or shrimps form the most important and economically significant group in the marine and brackishwater fishery resources. About 52 species of prawns and shrimps that are either commercially important or commercially potential occur in the Indian waters. This group represents about 13% of the total marine fish production of the country. Substantial quantity of prawns or shrimps, estimated at about one third of total shrimp landing of the country, are caught from estuaries and backwaters. Prawn fishery consists of Penaeid and non Penaeid varieties. The former constitutes about 52% of the total prawn landing. They are the commercially important prawns. Most of these prawns are subjected to exploitation in the juvenile stages and the highest catch are exported from Kerala. Vast concentrations of penaeid prawns have also been found in the exploratory survey conducted in the east coast as well. Backwater fishing of juvenile prawns known as 'Thelly' in Kerala has resulted in increased catches. This is likely to protrude the prawn fishery in the long run as it is bound to displace and exhaust the potential supply. Hence the MPEDA is seriously thinking of banning the export of 'Thelly' and of enforcing suitable measures for conserving and augmenting the prawn supply. These measures may include restrictions on the backwater fishing for juveniles, restrictions on selling of the goods etc. The commercial penaeid prawns, now exploited in the juvenile and other stages of their life in the estuaries, backwaters, and sea maintain their population mainly because of their capacity to produce large number of eggs. Protracted spawning, fast rate of growth, short life span and their ability to withstand wide environmental changes, make the prawns suitable for culture. Unlike in India, prawn culture has received much attention in Japan, Taiwan, Republic of Korea and Philippines. These countries have assigned high priority to prawn culture in their national developmental schemes. In our

country prawns form one of the foremost important group in our backwaters. The culture of these is being practiced traditionally in limited areas in Kerala and West Bengal. Here the fields are simple, where prawns are impounded. Source of Prawn seed is from the wild stock brought in by the incoming tidal current. This culture practice neither gets any attention nor management. Prawns are allowed to grow in the field for a short period, feeding on the natural food available in the environment. The success or failure of the operation depends largely on the availability of the seed in the nature, and the biotic and the abiotic conditions of the field. As a result of this, the production of prawns from these fields is very low varying from 500 to 900 kg/ha/year. Intensive researches carried out by various organisations on prawn culture have considerably advanced our knowledge in recent years.

Some data on the techno-economic viability of culture operation are also available. In the recent demonstration in the Santhom Brackishwater fish farm at Madras with monoculture of *Penaeus monodon* in a 1.14 ha pond, 587 kgs were obtained during the culture period of 80 days. In another demonstration at Narakkal in the canal in the coconut groves *P. indicus* amounting to 495 kg per ha were obtained during 90 days period of culture. Other field experiments at different centres have also clearly shown the possibilities and enhanced production rates. As the prawns grow very fast and reach marketable size within 3/4 months, it is found possible that a production rate ranging from 1000 to 1500 kgs can be achieved from a one hectare water spread during an year.

Penaeid prawns can be cultured in different types of ecosystems including the derelict waters such as salt pans, shallow canals and coconut groves. The basic resources of about a dozen species of commercial penaeid and palaemonid prawns, biologically suitable for culture and 2.6 million ha of estuaries and backwaters in addition to tidal creeks and lagoons on the edge of the sea offer bright prospects for the development of aquaculture.

Research, development, training and extension programmes and planning are essential pre-requisities for fully utilising the potential offered in this sector. Prawn culture operation includes selection of species, survey and location of site, construction of farm, controlled breeding and seed production, feed development, culture techniques, monitoring of the stocked prawns, control of diseases, maintenance of water quality, manipulation of environmental parameters, harvest, processing and marketing which require greater care and thrust. The areas of seed production and Farm Engineering should also get due attention besides harvesting and post-harvest technology.

Seed must be available as and when required by the farmers. Abundance of seed in the wild source fluctuates widely and depends on the opening stock and survival of the eggs and larvae. Mass production of seed is still to be achieved eventhough techniques of rearing prawn larvae in the laboratory on a small scale have been developed. The techniques should be perfected and a steady supply

of spawners must be ensured. Collection of spawners from breeding grounds is cumbersome and costly. Therefore, the researches have been intensified on the reproductive physiology of prawn with a view to evolve techniques for artificial breeding under controlled conditions and to standardize the techniques of mass production of seed leading to establishment of viable commercial hatcheries. Mass production of live food organisms to feed the larvae are equally important. A knowledge of nutritional requirements of larvae is also highly necessary to formulate suitable artificial feed. Our current knowledge on the aspects is inadequate.

Location and selection of suitable sites for prawn farming and construction of farm require reliable information on soil structure, water properties, flow pattern, fluid dynamics, engineering etc. The various types of diseases, parasites and other pathogens in the stocked organisms become very much important and must be investigated and remedial measures should be taken.

Fish genetics or prawn genetics requires greater study. Harvest and post-harvest technology also requires greater stress. Simple devices which would easily be employed by the farmers will have to be developed. Similarly low-cost processing technology which would be carried out on a small scale industrial level have to be evolved. Lack of information on the economic viability of prawn culture operation stands in the way of greater flow of finance to the industry. National demonstration programmes and the operational research projects would enlighten the potential industrialists on the techno-economic feasibility of the prawn culture. There is wide scope in our country for popularisation of prawn-cum-live stock farming similar to the system of paddy and prawn culture already practiced in Kerala in the context of integrated rural development. We require a large number of operational and trained farmers for the development and establishment of intensive prawn culture on a large scale.

In conclusion, may I venture to say that eventhough prawn or shrimp culture in India is only in the initial stage of experimentation, the prawn culture industry will in the long run revolutionise the rural economy of the undeveloped coastal zone. The important varieties of prawns can be earmarked for earning foreign exchange, while the minor varities can meet the protein need of local population. In the context of the national policy, which is oriented to the rural development, our planning strategy in this area should take into account the development of prawn culture on a large scale. Selected coastal and brackish-water areas in each maritime state may be identified for developing prawn farms by leasing and giving them to properly trained fish farmers. This may help accelerate the development of prawn culture and initiate the industry to take up prawn culture in new areas on a large scale. ○

INAUGURAL ADDRESS

BY

SHRI VAYALAR RAVI

Hon'ble Home Minister, Government of Kerala

Mayor Mr. Mathew Pylee, Chairman, Mr. Rao, Dr. Silas, distinguished guests and friends.

It gives me immense pleasure to be in your midst today to declare this National Symposium on "Shrimp Seed Production and Hatchery Management" opened.

I believe that I owe the right to be here because of my association with the Marine Products Export Development Authority for the last many years as a member of the Executive Committee of the Authority and also as a member of the delegation which had negotiations with the Food and Drugs Administration in the United States which had sorted out the major problem faced by the marine industry in India with USA sometime back.

I understand that this symposium is the second of this kind being organised by the MPEDA to popularise the shrimp farming and seed production in the country. The shrimp or prawn we call in India as Dollar because shrimp is one of the major items which earn the Dollars to such an extent. In the early 60's some adventurous entrepreneurs tried to export shrimp from this country worth about Rs. 4 crores. Now, the target of MPEDA is Rs. 300 crores, I believe that they could achieve, Rs. 285 crores so far. So it is a rapid growth in earning foreign exchange. By encouraging the marine exports to the major markets in United States as well as in Japan, the major consumable countries abroad, we could establish a good market even-though there is keen competition from countries like Mexico. Today many fishing nations face more problems not only with the market but also with production. Many countries abroad, like Mexico declare holiday during the breeding seasons. If conservation measures are not taken up immediately, here in our sea coasts - Bay of Bengal as well as Arabian sea - a decline may develop on resources. To certain extent it is true, and Dr. Silas and others could enlighten you more on this because, I am not a scientist myself. The production is coming down year after year. This is what I understand. The production is coming down because we catch more and more. Purseine nets and the country crafts fitted with 'Yamaha' engines are all making their way into the sea today and do indiscriminate fishing for more catch, irrespective of the time and season and without any holiday, our fishermen are going for fishing even all the 12 months in a year. These exploitations, if not restricted will reduce our marine wealth. We should observe holidays for certain period. Compared to our long coast lines, the present fish production appears to me very meagre. Is this the maximum catch that we can achieve from

our vast fishing area? This is a relavant question and the scientists have to tell, to the country and discuss the matter, whether the present production from our seas is sufficient enough to sustain the infrastructure which the country has introduced for the last many years. We have given encouragement to all kinds of fishing, including deep sea fishing. Many people have entered into this industry. So naturally the fishing activities have increased. But the production instead of going up, is coming down. So there is some urgency, to find out ways and means to stabilise the production level from the sea as well as to find out new avenues.

Here comes the shrimp farming, in the backwaters and estuaries along the Indian coasts. We have the well-known estuaries and backwaters such as Chilka lake, Pulicat lake and Vembanad Lake. Recent experiences in shrimp farming in the Madras region have resulted in heavy losses to the extent that the projects had to be closed down. We have to make the shrimp farming as a viable project, so that more people can be attracted. As I understand, presently, around 30,000 hectares are under shrimp farming while the resources is estimated at about 1.7 million hectares. To stock all these waters, we have to find out the sources and possibility of getting the seed in right time. It is the scientists to tell us when, where and how to produce the shrimp seed as the climatic conditions, temperature, etc. will be different for different states.

I believe that some experiments have been made to bring prawn seeds from West Bengal to Kerala, which is a very costly affair. So the shrimp seed production should be taken up in the respective state itself as it is initiated in Kerala. Also, the farmers who come forward for shrimp farming must be encouraged and supplied with quality shrimp seeds. Better seeds similar to the rice varieties like that of I. R. 8 which made a big revolution in agriculture sector are to be produced. The scientists should go-on experimenting, making more and more better shrimp seed varieties that can be supplied to the farmers in Kerala, in Tamil Nadu, in Orissa or whichever coastal states need stocking. It should also be made available in cheaper rates so that the culture operations will be a viable one. More efforts are needed by the Scientists and Technologists of MPEDA and other institutions who are coming forward to popularise shrimp farming.

Shrimp farming is the only way to cope up with the demand abroad by producing more shrimp in our available land and water sources. The MPEDA is giving technical and financial assistance to promote the shrimp farming, yet only a few people have come forward. I know, the MPEDA has earmarked Rs. 40 lakhs this year and it may go to crores in future. From the budget, they have earmarked money for the subsidy or grant for the shrimp farming and even they are ready to supply the seeds. But much people are not coming forward, because it is not popularised to that extent. Presently, here in Kerala farmers are following the traditional methods of farming called *"Chemmeen Kettu"*. This needs more scientific approach and should be popularised among people who come forward to take up shrimp

farming. I wish the MPEDA can do a big effort and can go to the extent to induce or encourage the farmers to come forward for shrimp farming not only for earning more foreign exchange but also as a source of employment among the rural people. There is also the question of quality control, in exporting to foreign markets. Americans are very sensitive about the bacterial or the *Salmonella* contamination. Naturally when the fishing is done in the far of sea or in the deep sea or in the area far from the land, there is every possibility of getting microbial or bacterial contamination in transit. The MPEDA should take all efforts to supply insulated fish boxes and ice boxes to preserve the catches in good condition. We should also produce films to show the fishermen how to be more hygienic and how the packing to be done in hygienic condition etc. All efforts have to be made, to make the foreign buyers satisfied that our products are the best and free from bacterial contamination. At the same time we should produce more fish from inland waters, backwaters and lagoons. The MPEDA can play a vital role in these direction. So naturally the efforts of the MPEDA deserves more encouragement and I wish this national symposium and all the scientists who have assembled here to put their views together to help, to attract and to popularise the shrimp farming. That only can prove beneficial to the poor fisherman, and farmers. I have suggested some of my views on the subject to make the venture a success. I hope good recommendations will come out during the symposium by which shrimp farming will attract more attention by the people from different parts of the country to come forward to utilize the available land, available water and marshy areas etc. for shrimp production which will help the country as a whole. With these few words, I conclude my speech and declare this symposium being inaugurated.

O

FELICITATION

BY
Dr. E. G. SILAS
Director, C. M. F. R. I.

Worshipful Mayor, Prof. Pylee, Hon'ble Minister, Shri Vayalar Ravi, Mr. S. N. Rao, Ladies and Gentlemen.

I am indeed very happy, that I have been asked to say a few words on this occasion and I feel that the comprehensive expressions given by Prof. Pylee and the critical points raised in the presidential address cover many of the areas that we are going to deliberate during the next two days, and I would like to add a few more points. One is that in this country we have a vast potential for the development of coastal aquaculture particularly for shrimp farming and this realisation has come in through mainly due to the short fall in our marine fish production, particularly the shrimp production. The landings of export quality penaeid shrimps, which stood at one time, in mid seventies, at 1,30,000 tonnes. Today it has come down to 80,000 tonnes. Naturally this is a matter of serious concern and how best the production could be augmented both in the capture fisheries as well as from culture source? Now, one of the systems by which we could do this is to take up extensive culture operations, not waiting for high cost technology to be developed as being contemplated. But to go in on area-wise development programme we need a sort of national policy on land and water use matters, and this is absent today or it may be different in different states. Unless, there is such a national policy, I do not feel that it will be possible to take up the programme in the national level covering all the maritime states. I hope that this will also be considered as one of the points which may come out of this symposium. I would also like to mention that whatever the technology we have developed in this country, it may be small efforts, but still it has received a very high appreciation in other parts of the world. The simple reason is that today we have developed one of the lowest cost technologies for shrimp culture as well as for the production of shrimp seeds in hatchery. We don't have commercial scale hatcheries at present, but we have at least developed the technology which can be scaled up to any hatchery system. We should be very proud of this, and I think those who are participating in the symposium would be exposed to this today and tomorrow, so that you can go back, enriched that we have some technology in this country which is viable. I also invite the press to visit Narakkal tomorrow morning and see in what manner we are going ahead with this low cost technology. Secondly, I would also like to mention that many of the large countries, I mean the other developing countries, have considered shrimp culture as on a priority area. 'Aquaplosion' or what you call intensive fish

culture is a major item in their priority list. Because of our requirements, in India now, we have also identified shrimp farming as a priority sector. But, it is not a goldmine, as there are a lot of constraints for the proper and successful culture of shrimp, which those who have entered into it would have realised. But, nevertheless, we feel that the technology developed to suit the agroclimatic ecosystem prevailing in our country and the species available to us for culture are indeed very good, and I am sure we will meet with success. One thing is that the low-cost technology we have developed is attracting quite a lot of attention outside. One of the largest concerns indicated in the presidential address we heard about has been with regard to the development made in Mexico and other countries, but they are all winding up because of the very high capital intensive system they have developed. They now realise that such a system cannot be sustained and supported. And at this juncture, I have got one point to say that in this country we should not think about importing this type of high cost technology, but try and develop and improve the low-cost technologies that we have developed here. May be, some countries have something to offer in identified specific areas such as genetics and improvement of stock and other things but that is only for the research people to go and look at and not for the culturist to think about at this stage.

With these few words, I wish all the best for this symposium and I hope that all the participants who have come here would benefit by the deliberations that we are going to have today and tommorrow. ○

Technical Session - 1

21 - 1 - 1983

SHRIMP SEED RESOURCES

Chairman : Dr. E. G. Silas

Lead Paper : Mr. R. Mallikarjuna Rao

Rapporteurs : Dr. M. J. George
Mr. A. G. Varghese

The Chairman after thanking the organisers, in his opening remarks, briefly highlighted the importance of the present symposium. He explained the format introduced by the organisers for the presentation of lead papers so as to generate meaningful discussions on the subject. As regards the topic of the session, he pointed out that, shrimp seed resources is one of the biggest bottlenecks and constraints encountered in the present day large scale prawn culture. He stated that the lead paper would highlight more on the subject, i.e., what has been done, what more has to be done to tackle the problems of prawn seed requirement. Further he said that the requirement of prawn seed could be met from two sources, namely from the wild and from the hatchery. Already some areas have been identified for shrimp seed in the surf areas as well as in the brackishwater environment along the coast. Regarding the seed source from the hatchery he mentioned about the two commercial hatcheries at Azhicode in Kerala, the first one being run by the State Fisheries Department, and the other one by Mr. K. H. Alikunhi. He also mentioned about the efforts of CMFRI, CIFE and other Institutions in hatchery production of prawn seed and hoped that more details about shrimp seed resources and hatchery systems would come from the participants during the course of discussions. He, then requested Mr. R. Mallikarjuna Rao to present the lead paper.

Discussion:

Mr. Isac Rajendran refering to the reported survival rate of 28.6% from postlarval production to juvenile phase observed whether such a culture operation could be economicaily viable for an entrepreneur. Mr. R. M. Rao said that the survival rate could be increased upto 80% or more through intensive culture involving feeding and careful water management. He further told that a survival of 40% could be achieved in extensive culture and the economic viability of operation depends not only on the nursery phase, but also on the care bestowed in the grow-out ponds.

Dr. V. D. Singh wanted to know how a correct fore cast of seed abundance

could be made when the seed availability is related to multifactors such as salinity, temperature, river discharge, rains, current, depth, substratum, suspended matter, lunar and diurnal cycles and pollution and how the industry could depend on such information. Mr. Rao observed that though the seed abundance is related to all the above factors, information on the general availability of prawn seed in the region would be useful to the farmers who collect the seed from nature for stocking. Clarifying a doubt on the effect of natural seed collection on the capture fishery from Dr. J. Bojan, Mr. Rao said that at the present level of exploitation, the capture fishery may not suffer and there is no immediate danger to the fishery. Dr. Silas, however added that in the long run it may affect the capture fishery, but by then we would be having an answer for this problem. For a querry from Mr. C. Suseelan, regarding the method employed for the rough estimation of natural prawn seed resources, Mr. Rao clarified that during his studies, natural seed resources were not estimated but only indices of abundance based on average number of seed per hour were worked out.

As a point of clarification, Mr. M. V. Natarajan observed that, collection of seed from nature with all restraint and uncertainities is not a solution for culture work as the number of seed required for stocking one hectare area is considerable. Even in the case of fresh water fish seed for inland fish culture, we have to go for induced spawning. Hence, the natural collection of prawn seeds is not the answer for commercial prawn farming.

Prof. D. V. Reddi in his remarks during discussion on the collection and supply of prawn seeds said that considerable quantity of prawn seed including those of *P. monodon* are available in and around Kakinada in Andhra Pradesh. Some entrepreneurs and fish farmers started "prawn seed banks" and are supplying seeds to private parties and Government Agencies to far off places such as Goa and Maharashtra. They have been trained under 'TRYSEM (Training of Rural Youth for self Employment). However they require financial support for running the business effectively. In this context he wondered, whether organisations like MPEDA can support them so that the resources could be utilised well. Mr. S. N. Rao, Chairman, MPEDA informed that if viable projects are proposed, the MPEDA would definitely come forward to finance or support such schemes.

Different aspects such as sorting out of species-wise seed from the mixed natural collection, method of collection, best time for collection, details of gears used, their designing, fabrication and quantity of seed now collected by the private parties in West Bengal were discussed, in which Mr. K. V. Devasia, Mr. C. Suseelan, Mr. R. R. Honavar and Dr. T. J. Varghese participated.

Dr. Silas in his concluding remarks thanked Mr. R. M. Rao for highlighting the important points in the lead paper, and told that the symposia and seminars are the forums wherein we can find out the lacunae existing and studies so far made in various fields. The excellent surveys done by Tamil Nadu and by the joint project of MPEDA and CMFRI on the assessment of prawn seed resources

along the coast of Kerala and Karnataka had identified the areas of natural seed availability in these regions. Similarly, information is also available in several reports and papers on the distribution and seasonal fluctuation of prawn seeds. MPEDA would supply the literature on the available and additional surveys on seed resources. Thanking all the participants for a meaningful discussion on the subject and the organisers for giving him an opportunity to participate in the deliberation, Dr. Silas concluded the session.

Technical Session - 2

21 - 1 - 1983

LARVAL NUTRITION

Chairman : Dr. M. J. Sebastian

Lead Paper : Dr. P. Vedavyasa Rao

Rapporteurs : Mr. V. Venkatesan
Mr. B. Vishnu Bhat

The Chairman in his opening remarks pointed out that 'Larval Nutrition' is one of the most crucial aspects in running a commercial hatchery successfully. As regard to rearing the early larval stages there is not much problem especially if they are herbivores. 'Green water' provides a suitable medium. But when the larvae show preferences for zooplankton or food of animal origin, larval nutrition becomes a complex problem. There are two major ways of solving this problem. One is to culture prefered zooplankters in large quantities and supply them as live feed for the larvae. The other, more recent method, is to provide artificial feed or balanced compounded feed of the required particulate size which will remain suspended in water so that the larvae can feed on them. Here, there is a danger of pollution of the culture medium. However, Indian Scientists Mr. K. H. Alikunhi and Mr. K. Hameed Ali have achieved remarkable success using minced crustacean flesh as larval feed for the penaeid prawns. The details of this technology is to be transferred urgently to the prospective farmers wishing to establish commercial prawn hatcheries. The Chairman hoped that during this Symposium much light will be thrown on the larval nutrition of the commercially important prawns.

The Chairman then invited Dr. P. V. Rao to present the lead paper on 'Larval Nutrition'. The paper was presented by Dr. Rao and thereafter the discussion followed.

Discussion :

The first part of discussion participated by Mr. K. H. Mohamed, Mr. Hameed Ali and Dr. P. V. Rao centred around particulate size of the feed. It was informed that larvae at different stages feed on different particle size food. According to Jones *et al.* optimum size of the food particles for various stages were 10μ for protozoea, 28μ for mysis and still larger size for postlarvae. Mr. Hameed Ali reported that the larval stages feed on still bigger size particles of wet diet (Protozoea: 180μ, mysis: 250μ, Post larvae: 300μ).

Evincing keen interest in the recent development of microencapsulated diet, their use in larval rearing, survival rate, the deliberation noted the reduction recorded in the rearing period in *Macrobrachium* and in Panaeid prawns and opined that further research is needed on the large scale use of these diets to obtain higher survival rates.

The crustacean tissue feed developed by Mr. Alikunhi and Mr. Hameed Ali and offered to larvae in a state of suspension attracted a good deal of discussion on whether the larvae feeds on these tissue particles or on the phytoplankton that develop in the culture tank. Mr. Alikunhi explained lucidly the preparation and successful use of the feed in the hatchery at Azhicode. It was also informed that the neutral bouyancy of artificial feed as well as aeration help them to remain in suspension. Using artificial feed a survival rate of 70–75% has been recorded.

Turning to the rearing of *Macrobrachium* larvae, Mr. AVP Rao observed the varying results recorded by different workers. To improve the survival rate and to reduce the period of larval rearing Mr. Alikunhi suggested to feed the larvae by zooplankters such as *Moina* or copepods, either cultured under controlled conditions or collected from the natural sources. Informative discussions were also held on the requirement of Polyunsaturated fatty acids and diseases of larvae in the hatchery in which squadron leader Mr. Parasnis and Mr. Ifthekar Mohiuddin participated.

After the discussion, the Chairman, in his concluding remarks summed up the important points of practical utility in hatchery management, presented in the lead paper. As penaeid and palaemonid larvae have different feed requirements, the hatchery practices in the rearing of the early larval stages of these two groups are quite different. For example in rearing *Macrobrachium* larvae, phytoplankton may not serve as an essential food material, but is helpful in keeping the quality of the water and as a feed for the zooplankton. Outdoor systems of culture are less expensive, but the production is not as intensive as in indoor system, where the culture is done under controlled conditions. Live food organisms like *Artemia*, rotifers, cladocerans and copepods still play a major role serving as principal food during part or whole of the larval development. An important recent development in larval rearing is the introduction of compounded feeds. Soyabean powder, marine yeast, crustacean flesh etc. have been used by various workers. The latest introduction is the microencapsulated feed, which is under experimental stage only. The use of growth promoters in feed is also in

the experimental stage. The optimum requirement of micro and macro-nutrients in the feed for larvae has been recently studied and reviewed by Dr. P. V. Rao. Whereas, penaeids require 10 aminoacids in their diet, the palaemonids are presumed to synthesise these in their body. The observation that, given good food like live zooplankton, the larval life-span of *Macrobrachium rosenbergii* could be cut short to 24 days would be of great importance in running shrimp hatcheries in a more efficient and economic way.

The Chairman thanked Dr. P. V. Rao for presenting such an exhaustive review paper on larval nutrition and for his participation in the discussion. He also thanked the Rapporteurs. He expressed his gratitude to the organisers of the Symposium for giving him an opportunity to participate in the deliberation of the Symposium.

Technical Session - 3

21 - 1 - 1983

BROOD STOCK DEVELOPMENT AND MANAGEMENT

Chairman : Dr. C. T. Samuel

Lead Paper : Mr. M. S. Muthu

Rapporteurs : Prof. D. V. Reddy
Mr. R. N. Padhi

The Chairman, Dr. Samuel thanked the organisers for giving him an opportunity to Chair the session and to participate in the National Symposium. As an opening remark, he mentioned the importance of brood stock development and management in the context of problems encountered in the availability, collection and transportation of spawners from wild. This field gets more importance due to the large scale prawn farming activities that are taking shape in our country. Development of brood stock is of recent origin, nevertheless much headway has been made but much more have to be done in respect of some species such as *P. indicus* and *P. monodon*. The bio-environmental features have to be studied in depth, as these parameters have a particular role in the brood stock development in the confined water. He then requested Mr. M. S. Muthu to present the lead paper.

Mr. Muthu presented an exhaustive review on the subject.

Discusson:

As water quality is of paramount importance in the systems where brood

stock is maintained, Mr. K. V. Devasia and others initiated the discussion from this aspect enquiring about the level of toxicity of nitrite and ammonia, the factors accelerating nitrite toxicity and the test species used for such studies. Mr. Muthu replied that toxicity of nitrite to penaeid prawns was studied by Wickins (1976). In *P. indicus* a nitrite level of about 6.5 mg/l No_2– N reduced the growth. Decrease in dissolved oxygen accelerates nitrite toxicity which is generally observed to be more in freshwater than in saline water. The maximum acceptable level af ammonia is 0.1 mg/l NH_3–N for penaeid juveniles. He further observed that as long as the biological filter is functioning properly, ammonia and nitrite will not pose problems for brood prawns. Regarding fluctuation of pH in seawater circulated through biological filter, enquired by Mr. Bright Singh and Mr. Pande, Mr. Muthu pointed out that the pH declines from 8.2 to 7.5 or 7.4. This pH can be stablised by having oyster shell pieces in the filter, but the fall in pH cannot be prevented as it is a natural consequence of the nitrification process. The pH can be increased by adding appropriate quantities of the sodium carbonate or slaked lime to the pools.

Induced maturation of prawns through eye stalk ablation was discussed in great detail. The efforts made at Narakkal to mature and spawn *P. indicus* in captivity without eyestalk ablation but through manipulation of environmental parameters were explained. However, it was found that the percentage of females that attained maturity by this method was smaller than those attained through eyestalk ablation. Mr. K. H. Alikunhi mentioned that females of *P. merguiensis* matured in brackishwater ponds have been successfully spawned in Indonesia. Specimens of *Metapenaeus brevicornis* frequently attain maturity in ponds and such females have been spawned under hatchery conditions in Indonesia.

Prof. D. V. Reddi suspected whether the electrocauterisation of eyestalk would cause heavy mortality. It was observed that no mortality occured due to this method of ablation. Further the survival was 100 percent. Mr. B. Vishnu Bhat was informed that inducement for ovarian maturation to the mature stage by eyestalk ablation can be got within a short period of 4-5 days in *P. indicus* while in *P. monodon* it takes 10-15 days. There is no other quicker method immediately available to induce maturation in prawns. It is also mentioned that *P. indicus* female rematured and spawned seven times after eyestalk ablation and there was no marked decline in the fecundity rate or the number of eggs spawned but the hatching rate declined in the later spawnings. Besides, prawns did not grow in size in the brood stock pools indicating that all the energy was diverted for production of eggs rather than utilising it for growth. *P. monodon* of about 200 mm size is suitable for eyestalk ablation. While no abnormalities were observed in the prawns with unilateral eyestalk ablation, bilaterally ablated prawns frequently swim in a spiral manner.

To a question on 'white Ovaries' in the Philippines due to Mixosporidian infection, Mr. Muthu said that, in India, such an infection has not been observed

so far in the culture specimens. However, he has frequently observed wild *P. indicus* females at Madras with the ovary completely destroyed by Mixosporidian parasites. Miss Dawn Rhoda Jamandre from Philippines, stated that they did observe this phenomenon in their country and there was no cure suggested so far. The breeding was not affected, but hatching rate was found to be poor in such specimens.

Reabsorption of ova was often observed in maturing prawns. Commenting on this, Mr. A. V. P. Rao stated that maturing female prawns *(P. indicus)* with brown coloured ovaries when fed with the flesh of trashfish, were observed to loose the mature condition in about 24-36 hrs. However, he wanted to know whether resorption of gonads could take place in such a short time. Mr. Muthu fully endorsed the observation and observed that this might be due to handling stress. Penaeid prawns like *P. monodon* are very sensitive in this respect.

Degradation on water quality, its effect on the bacterial proliferation and the consequent effect on the animal was commented upon by Mr. Bright Singh and it was stressed that studies in this aspect should be made to improve the water quality. The author also clarified a question that there is no beneficial effect due to more lipid content in the diet of brood stock.

After the discussion the Chairman in his concluding remark said that the coverage of the paper has been elaborate, quite a lot of information has been gathered and most of the aspects of brood stock development and management have been covered. He thanked the author for presenting such an exhaustive lead paper and the delegates for co-operation in the conduct of the session and for fruitful discussion.

Technical Session - 4

22 - 1 - 1983

HATCHERY PRODUCTION OF SEED

Chairman : Dr. Vijai Dev Singh

Lead Paper : Mr. K. H. Mohamed

Rapporteurs : Mr. K. Raman
Mr. V. Krishnamurthy

The Chairman, at the outset, thanked the MPEDA for the kind gesture shown to him. As opening remarks, he briefly outlined the importance of the topic and the field visit to Narakkal Prawn Culture Laboratory (NPCL) of CMFRI. He expressed his satisfaction and appreciation over the activities and commended

the achievements of CMFRI in prawn seed production through hatchery technology. Besides MPEDA and ICAR Institutes work on prawn farming promotion activities, Ministry of Agriculture is also very keen to develop this virgin field. He further said that the Central Government had released Rs. 121 lakhs as grant to all the maritime states to meet 50% expenditure for setting up the demonstration farms following the technology developed by the Fisheries Research Institutes in their respective regions. Observing the success at Cochin and at various centres, a new scheme called 'area development' has also been started from the current year. The scheme, will have Rs. 500 lakhs as Central Share and an equal amount could be borne by the respective operative state government. The scheme also envisages setting up of hatcheries for the first time in the 8 different maritime states. These states have been requested to make use of the indigenous method already developed in the country in hatchery technology. He hoped that all the state governments would implement the scheme expeditiously to achieve the success in the field. On concluding his opening remarks, the chairman requested Mr. K. H. Mohamed to present the lead paper.

The paper presented by Mr. K. H. Mohamed threw light on the techniques that are followed for production of seed through hatcheries in NPCL and elsewhere in India and abroad.

Discussion :

Mr. N. M. Magar, raised a question on the physico-chemical changes involved in the specimen placed in spawning tank by addition of Ethylene diamine tetra acetic acid (EDTA) and role of EDTA in spawning activity. Mr. Mohamed replied that EDTA is a metal chelator and it has been widely used by the Scientists engaged in culture work. The beneficial effect of this are well known as it helps in quicker hatching of eggs and reduces the bacterial load, but its role on spawning is yet to be understood. Similarly the exact nature of its influence on the larvae or its environment is not clearly known and it is a field on which much work is to be done. Explaining further, the details of hatchery operation, it was informed that although reduction of salinity for post larval rearing was not essential, the larvae often showed stunted growth and it would be desirable to provide the salinity of the natural habitat of the Post larvae to achieve better growth.

For a querry from Mr. R. R. Honavar on the failure of electricity and its effects on hatchery production of seed, Mr. Mohammed informed that if all electrically operated facilities come to stand still it would cause disastrous effects on the larvae. As an alternative, non-conventional energy source such as solar energy could be used for operating the equipments. These are however, not standardised yet and some institutions are still working in these lines. Regarding mass scale mortality of *P. Indicus* larvae and the reason for such disaster raised by Mr. Bright Singh, it was informed that several times such mortalities occured at NPCL and the reasons were very many, including breakdown of systems caused by electricity failure, poor water quality, inadequate feeding condition and diseases. On the

relationship between the nature of bacterial flora of water and health of the larvae, Mr. Bright Singh explained that he had found six genera of bacteria in the rearing medium during the early stages of development of prawn larvae and when they reached the post larval stage only one particular genera remained in the medium causing large scale mortality. Perhaps, the bacterial flora might also increase when the larvae start feeding and the faecal matters discharged by them in the medium would have caused the mortality. Concluding the discussion on the water quality, mortality and related aspects, Mr. Mohamed opined that the aspects such as the role of microorganisms in the rearing medium and dissolved nutrients should be further studied to improve the hatchery systems.

Mr. J. N. Pande wanted to know the best feed among live feeds, prepared feeds and formulated feeds for a commercial hatchery at present. Mr. Mahamed replied that different types of feed stuffs were used with considerable success by different workers. The choice of the feed would depend on the facility, conveniences, expertise and availability of material in a given place. Live feeds are good as they do not pollute the environment. However, as compared to the cost of monoculture of live food organisms, prepared feed would be much economical. Feeding of larvae with suspension of squilla *(Oratosquilla nepa)* tissues was discussed by Mr. A. V. P. Rao and Mr. Alikunhi. It was clarified that the fat globules generally do not conglomerate and therefore there is no chance of larval appendages getting stuck up in lumps of fat. The fat content of *Oratosquilla nepa* is very little. No difficulty due to feeding of larvae with squilla tissue has been experienced at Azhicode hatchery. Further the system of feeding is also not so complicated as this could be handled by inexperienced persons.

Regarding fungal infection Mr. Mohamed said that at the NPCL such infection was occasionally observed and if such infection noticed the batch of larvae was usually discarded and only after disinfection, new batch were taken for rearing. The purple patches frequently noticed in the lining of plastic pools, were also found not harmful to the larvae.

Wounding up the discussion, Dr. Singh congratulated Mr. K. H. Mohamed for presenting a detailed paper on the subject, which covered various aspects of hatchery production of seed. He said that the technology developed in our country could be effectively and efficiently used for production of more prawn seed in hatcheries. He thanked the audience and delegates for a fruitful discussion and co-operation.

Technical Session - 5

22 - 1 - 1983

DESIGN, MANAGEMENT AND ECONOMICS

Chairman : Mr. K. H. Alikunhi

Lead Paper : Prof. D. V. Reddi

Rapporteurs : Mr. P. R. S. Thampi
Dr. J. Bojan

The Chairman Mr. K. H. Alikunhi thanked the MPEDA for giving him an opportunity to share some thoughts on this important problem of shrimp seed production. He briefly reviewed the deliberation during the previous sessions of the symposium on aspects such as seed resources, brood stock development, larval production through hatchery and larval nutrition and observed, against the background of information available, how little we actually know of the technology of successful commercial seed production in the country in our environment. In India we have detailed biological information on marine prawns. But very little has been done in utilising this information to produce the seed of the prawns required by the industry and to encourage the production of prawns.

The lead papers presented in the earlier sessions have at length described the technology developed and followed in our country in commercial seed production/on going research work and advancements made in various institutions. The papers also highlighted the fact that we have not reached a stage to consider a proper system, its layout or design for hatchery production of seed on a commercial scale. Economic consideration of operation of a commercial hatchery is not available. The hatchery at Azhicode, sponsored by the Government of Kerala has been operating for the last 4 years producing between 2–5 million seeds of *P. indicus, P. monodon* and *P. semisulcatus* every year adopting the new system of feeding developed by Mr. Hameed Ali. The seed has been made available to the farmers within Kerala and outside. But as a Government undertaking it has certain advantages as well as disadvantages and the system may not be amenable for a proper economic assessment.

However, in 1978 during the first national symposium on shrimp farming at Bombay, the consideration for a hatchery was of a theoritical nature, but now we could share some thoughts and discuss the design, management procedure, and economics of a hatchery system on some practical experience. Nevertheless, due to inadequate information available on various aspects of the hatchery as indicated in the earlier session,

such consideration could be still mostly theoritical in nature.

With this introductory remarks Mr. Alikunhi requested Prof. D. V. Reddi to present the lead paper.

Prof. Reddi, thanked the organisers and informed the gathering about the inability of Dr. Dwivedi to present the lead paper. He further said that the present paper, a contribution of Central Institute of Fisheries Education (CIFE) is based on the experience of running hatcheries at Bombay and Kakinada and describes the technology followed at CIFE and the factors limiting production of prawn seeds. The paper, however, restricts its scope to prawn seed production and its art as there is inadequate data to discuss design, management and economics of shrimp hatcheries. In conclusion, he pointed out the immediate requirements of developing this virgin field to meet the seed demands by various private/public agencies.

Discussion:

Initiating the discussion, Mr. D. M. Abdul Hameed said that in the context of the scheme for assistance in setting up hatcheries from the Government of India, the various state governments would need a design of a model hatchery and hence he wanted to know the existence and availability of such a design with a list of all requirements. If not, whether the same could be designed and supplied by any agency for immediate implementation of the scheme. Prof. Reddi replied that different Institutes follow their own d fferent designs and equipments. The design of a hatchery could be specified with a production target of a minimum of one million seed. Several workers often quote the design of the Azhicode hatchery and the delegates would be able to know more about the design the next day, when they visit the hatchery. Mr. K. H. Mohamed informed that CMFRI has a design of a model prawn hatchery which is taken up for construction at Narakkal. The hatchery is expected to come into operation within about 6 months time. He further said that indigenous models can also be prepared for those who are interested in having such designs. However, before designing hatchery and setting up at a place, several points such as location, suitability, water supply arrangements, intake of waters, availability of clean, clear sea water, filter systems, and capacity of the hatchery have to be taken into consideration. The machinaries and equipments would differ according to the capacity of the hatchery. So a single thumb rule cannot be used in designing a hatchery. Mr. Alikunhi further added that he had prepared a hatchery design with a initial installed capacity of 20 million seed/year for the Tamilnadu Fisheries Development Corporation at Madras, which would run into operation in the current year. The capacity of this hatchery could be raised to 35 million seeds in the course of another 5 years with the same machinaries, and latter to 50 million seeds. Mr. R. R. Honavar at this juncture desired to know at what scale of activity a hatchery becomes viable? Whether any Institution has carried out the data on the factors which play important role in controlling the cost of the seed including cost benefit analysis of the operation.

Mr. U. K. Gopalan commenting on the viability of hatchery said that 'a seed

in need is a seed indeed' and in his view a hatchery becomes viable in Kerala, if it could supply prawn seeds during November or December as almost all the traditional and other farmers start stocking of their ponds in November when large amount of seeds is required.

Mr. Alikunhi fully endorsed the views expressed by Mr. Gopalan and said that after all we are only starting hatchery production of seed, and we should have little more patience to understand and learn the hatchery technology. He further informed that as regards to the supply of seeds during November, he had his own reservations due to the fact that, in Kerala, there is a rainy season which extends from June to September and during which time there is a large influx of freshwater into the estuarine system which makes the coastal waters almost fresh. In such a situation getting seawater is a problem which necessitates to take up other steps to get saline waters. However the problem of getting spawners could be overcome as Mr. R. M. Rao said that spawners are available throughout the year in natural situation or as Mr. Muthu said the spawners could be produced in laboratory under artificial condition by induced maturation. Thus there are certain limitation which make the operations of a hatchery limited to some particular time.

Dr. V. D. Singh, suggested that MPEDA should take the lead to consolidate the details of the physical facilities/ infrastructural facilities required for hatcheries as it had taken the lead in organising this symposium, so as to supply the needed information for the benefit of the industry.

Mr. Alikunhi complimented the suggestion raised by Dr. Singh and stressed that it is very difficult to have a standardised general design for a hatchery. For example, the design already prepared for Tamilnadu Government may not be applicable to other locality as condition and infrastructural facilities available would be quite different. Further, the system of culture to be adopted makes a profound impact on the infrastructure to be provided. Analysing the various systems available at the moment in the country and elsewhere, he said that 3 systems of operations are followed. They are 1) The traditional Japanese system, which is about 4 decades old; 2) The Galveston system, which is an offshoot of the Japanese system; 3) The Indian system developed very recently.

The Galveston system, developed in the United States has now gone to South America, and at present modified Japanese system is adopted in the United States. The only hatchery which is functioning in the United States under the M/s Mari Farms Ltd. produces about 370 to 380 million seeds/year which is as much as the total seeds produced by the private and public hatcheries in Japan. The Galveston technology is the most sophisticated technology with small containers, automatic feeding and specialised system of algal production. In contrast to this, the Indian system, which is developed very recently by Mr. Hameed Ali (1980) is a very simple system where the larvae are fed with an artificial feed prepared from the readily available raw material *Oratosquilla nepa* which at present constitutes 20% of the trawl landings in the west coast of India

and used as manure for coconut plantations. If this raw material is not available, as an alternative, the large landings of non-penaeid prawn *Acetes indicus* in Maharashtra could be well utilised as an excellent feed for the prawn larvae. So the system to be adopted would specify the design which would indicate the minimum requirements of the hatchery. Depending upon the system, operational personnel, watch and ward personnel and other management measures would be different. Therefore, it is very difficult to give a standardised design, applicable to every places but it is easy to give machinary required for a hatchery of a particular capacity for a particular species. This would be subjected to modification when applied to various locations. Under these circumstances he said, it is very difficult for the CMFRI or MPEDA to provide such information to various states.

Describing the new larval rearing system developed in India, Mr. Alikunhi said, the technology is available for the last 4 years and details of the system and method of operation have been published. It is a simple but dynamic and intensive system of culturing prawn larvae. It is also followed by an entrepreneur with good results.

The intensity of naupliar density of 300 to 350 L and postlarvae of 200 to 215 per litre in the Indian system is a very high figure, when compared to the reports of 133 postlarvae per litre by Cook and Murphy. While maintaining such a high density, in a system where non-living food is given frequent exchange of water and feed density should be appropriately maintained. This system has been continuously tested successfully for the last 4 years at the Azhicode hatchery as well as in his own hatchery ta Eriyad, Mr. Alikunhi said.

Regarding the size of food particles used in feeding the various stages of larvae, Mr. Alikunhi informed that the 2nd zoeal stage of *P. japonicus* has been found feeding on the *Artemia* nauplii of size 330 μ. Feeding of zoea and subsequent stages of *P. japonicus* with rotifers is a regular system in Japan. So it is not necessary that the larvae should consume only the small size particles or a particular feed to be used to obtain the maximum survival of the larvae. It has been demonstrated that mysis stage continue to feed phytoplankton without shifting to zooplankton and subsist on that. Such a subsistance is well known in carp seeds i. e. they feed on the available food and thrive. He said that Schaperclaush as classified feeds of fish larvae into 3 categories. 1) Normal food 2) Occasional food and 3) Emergency food. Normal food is the best available food and by which the survival is the maximum. Occasional food is that which it may consume or it may just leave. Emergency food is that the larvae consumes when nothing is available. He further wanted to know from the CMFRI Scientists, whether the zoeal stages of prawn larvae really make use of the diatoms as in many case it was found that the diatoms come through the vent of the larvae undigested. Mr. Muthu replied to the querry that they did not find complete diatoms, but only empty frustules in faeces which obviously means that they are utilised. He further said that, they have studied the feeding mechanism of the larvae while consuming *Chaetoceros*, which are in chainform

and an individual cell size of 5-8 μ. The maxillary filters which is an ideal filtering mechanism, is used to filter the food which is then macerated with the mandibles and consumed without any problem.

Regarding management and economics, Mr. Alikunhi observed that the technology developed in India is available for the last four years and has been tested under very rigorous conditions at the Regional Shrimp hatchery at Azhikode. One of the greatest test the technology passed through was by achieving the production of hatchery seed by employing predominently contingent and casual labourers who have no interests other than getting their monthly salary. The success of hatchery under such circumstances clearly demonstrate the viability of the technology.

Commenting on Mr. Mohamed's statement on the difficulty of transfering the technology to farmer, he said, though he conceeds the difficulty but that is surmountable. Giving an example, *P. monodon* seed which we are all concerned much are being produced in a number of hatcheries in Taiwan by farmers. Similarly, the very complicated techniques of production of larvae of *Macrobrachium,* which was developed in Malaysia and more efficiently in Hawaii, is now a cottage industry in Thailand. If such things could happen elsewhere, it could be possible for us also to transfer the technology to our farmers who could in turn can take up the technology and produce prawn seeds.

Continuing on the subject, he said that our hatcheries so far are depending on the naturally available spawners from the sea. Recently considerable work has been carried out on induced maturation. As a matter of fact, he (Mr. Alikunhi) was the first to ablate the eyestalk of *P. monodon* and *P. indicus* which subsequently matured and spawned. That was also the first instance of pond reared specimens maturing and spawning as a result of eye stalk ablation. As his experience goes, the ablated prawns do not give satisfactory results eventhough they mature and produce eggs. The eggs produced by naturally collected spawners are much more than the eyestalk ablated specimens. He pointed out that for production of 1.2 million larvae we only need 8 naturally matured spawners, but as per Mr. Mohamed's report he had used 41 specimens at Narakkal to produce the same quantity of seed.

Regarding the economics of commercial hatchery, it is difficult to furnish reliable data since we do not have commercial hatcheries in India in its strict sense. Eventhough a commercial hatchery is working at Azhikode, it is not possible to work out the economics. During 1980, Mr. Alikunhi said that he had tried to find out the cost of production of PL 5 of *P. indicus* produced at the Azhikode hatchery estimated as Rs. 2/- per 1000 larvae. The cost of production of seed of *P. monodon* was also the same. However, at the moment it would be premature to give any economics of hatcheries unless we come to a standardised practical technology which everybody would apply.

Mr. Alikunhi opined that the seed banks as suggested during the discussion

could be considered and organisations like MPEDA should come forward and organise such seed bank in various parts of the country. Mr. U. K. Gopalan said that in Kerala between Azhicode and Alleppey there has been collection of large amount of prawn seeds to the tune of 600 tonnes of size 18 to 25 mm by the traditional fishermen. He has given improvised device for collection of this seeds by the fishermen while paddling the boat. If this collection, pooling etc, can be handled by Panchayat or other organisation it can be developed as a prawn seed bank in the coastal Kerala which can supply seeds to prawn farmers. So he said that there is an immediate need of having a seed collection and storage industry for the benefit of the prawn farmers.

Concluding the discussion, Mr. Alikunhi thanked the audience for a patient listening and making the discussion useful. He also thanked Prof. D. V. Reddi for presenting the lead paper. O

Plenary Session

22 - 1 - 1983

Chairman : Mr. S. N. Rao

Rapporteurs : Mr. R. Ganapathy
Dr. G. Santhana Krishnan

The concluding/Plenary session of the two day National Symposium was started with the opening remarks by the Chairman of the session Mr. S. N. Rao, Chairman, MPEDA. He said, as a person being responsible for organising the Symposium, he is very happy to be in the company of scientists and technologists who have devoted their efforts to this particular subject. Though MPEDA is mainly a marketing organisation, the declining trend of shrimp production from the capture fishery resources and demand for the raw materials by the exporters have made them to venture into the extention work of popularising the aquaculture production of shrimp for augmenting the national food basket. The present symposium, second in the series, was only a reflection of some of the activities of MPEDA in this particular field. At the moment, it is building up an extensive extension staff, and recruited a number of young people. With their active co-operation only the present symposium was planned to have a better exposure of the field for meaningful discussion and exchange of views among those concerned in shrimp culture. He further said that he was very happy to note that the interaction had been very good; and they now know where they stand.

As a matter of fact, shrimp culture is a growing industry and is some what of a fashion in the United States, South America and Far East countries. The growing demand for shrimp in America and the present deficit supply in United States is expected to be stablised by the continuous production of shrimp through aquaculture in Ecuador, Panama and Peru. So shrimp culture would satisfy the additional demand of USA and other markets in future and cultured shrimp are well accepted due to its excellent quality. In India too, the commercial shrimp farming activities are just picking up and would be needing large quantity of prawn seed in due course and in this context organising the symposium is quite topical and everybody is benefited by exchange of ideas and views. Though the theme or topic of the symposium is highly technical, the available information is meagre as the subject is of very recent origin. The symposium, he hoped, would help the scientists and technocrats to carry forward the

technology already developed in the country and generate more information to discuss in the next symposium. With these few remarks he requested the Chairman of the respective Technical session to summarise the draft recommendation and the delegates for suggestions, amendments, deletion and acceptence.

Dr. E. G. Silas, Chairman of the session "Shrimp seed resources" said, the lead paper presented by Mr. R. M. Rao highlighted many general and specific problems connected with the assessment of seed resources and presented the following recommendations.

1) Although some information is available in the country in some areas on the resources of seed of important cultivable species of prawns in certain regions, there is lack of data on the quantitative and qualitative aspects of the seed resources and their seasonal abundance. In view of the importance of these aspects in making use of the seeds for stocking and culture purposes, it is recommended that proper assessment of prawn seed resources and their seasonal abundance in the coastal waters may be undertaken expeditiously.

2) To make use of the seed resources available in different parts of the country, and to distribute the seed to farmers, necessary organisational set up has to be evolved. With this in view, it is recommended that action may be taken for establishing 'seed banks', supported by prawn hatcheries in the different maritime states.

Commdre. K. M. V. Nair initiating the discussion, wanted the Chairman to specify the agency which will organise seed banks and how it will take shape in supplying the seeds to the farmers.

Dr. E. G. Silas suggested to organise collection centres, to collect, pool and supply seeds to farmers in the initial stages which may be supplemented subsequently by hatchery produced seeds. At this stage the seed banks could be well organised under the purview of State Fisheries Departments. As one of its extention activities this may be taken up to popularise the seed bank, giving training in the collection, segregation, identification and transportation of seeds. Mr. K. H. Alikunhi wanted seed banks to be a seperate organisation without getting associated to the shrimp hatcheries as the functions of these two are quite different. He further said that such activities can be effectively handled by the Panchayat; or Farmers Co-operatives for the present and later by a seperate organisation, or other body can be created. Mr. Gopinath said that each state should have a seed bank to distribute the seeds to the farmers as and when they require.

Mr. K. S. Purushan, said that we should not go on collecting the seeds from the nature as it would ultimately deplete the production from the natural water bodies either in the long run or in the near future. In Kerala, there is already a conflict between the seed collectors and the traditional fishermen, as the latter completely depend on the juvenile fishery of prawns in the backwaters of Kerala.

So collection of seeds from these waters for setting up seed bank will harm the fishermen who are making a living out of fishing activities. It was suggested, in this context, instead of going for seed collection from the wild, we should think of producing seeds through hatcheries, and later to consider the seed bank.

Dr. Silas welcomed the various suggestions made and opined that as we have not developed the prawn culture system to such a large scale, it is not necessary to go in for production of seeds through hatchery immediately as the seeds collected from the wild might be sufficient at present. At the same time, it should be our vision to set up seed banks in the long run with seeds produced exclusively through hatcheries. In the interim period we should immediately set up the seed banks supported by wild seeds rather than waiting for the seeds from hatcheries. The idea is that we should bring as much areas as possible in farming system in the shortest period by way of utilising the seeds available from the nature, and the increased demand for the seed can be met through hatcheries After the discussion the modified recommendations were accepted.

In the absence of Dr. M. J. Sebastian, Chairman of 2nd session "Larval Nutrition" his draft recommendations were read out as follows for discussion.

1. Existing information regarding the infestation of various larval stages of Indian prawns by pathogens is meagre. Intensive efforts should be made to investigate larval disease and to evolve control and precautionary measures to prevent the infection. Methods to treat the infected larvae are to be evolved and popularised.

2. Economically viable balanced and suitable compounded feed should be prepared for larval feeding.

3. More information is needed to increase the storage value of the live feed without altering its nutritive value.

Commdre. K. M. V. Nair again wanted to know the agency which will popularise the formulated artificial feeds and take responsibility of production of such artificial feeds. Mr. K. H. Mohammed observed that the Narakkal Prawn Culture laboratory has already formulated the feed which has given excellent results, and it would be better if any private agency takes up production and popularising the formulated feeds in the best interest of the industry. Dr. G. Santhana Krishnan added that, still more research is needed to perfect the viability of feeds. Once the economic viability of the feed technology is proved the entrepreneurs would come forward to adopt the technical know-how available. This was proved in the field of product diversification promoted by MPEDA in the recent past.

The recommendation of Technical Session III and IV, were presented by the respective Chairman Dr. C. T. Samuel and Dr. V. D. Singh as given below.

Session III

1. Considering the growing need and importance of shrimp seed production, suitable and dependable methods of brood stock development applicable for each species of cultivable shrimp should be developed.

2. Transfer of the technology for brood stock development and management should be incorporated in the training programme.

Session IV

1. The hatchery technologies for prawn seed production developed by the Research Institutes and others in the research field may be consolidated along with the design, infrastructure facilities and cost of operation for the benefit of developmental agencies, private entrepreneurs and farmers to set up hatcheries so as to produce and meet the requirement of seed for large scale culture of prawns in the country.

The draft recommendations were modified and accepted with the approval of the house.

The Chairman of Technical Session V Mr. K. H. Alikunhi said that, as there is no much work done in design, economics and management of commercial hatcheries in India, he felt, it was very premature to make any suggestion or recommendation at this juncture. However, he read out the draft recommendations as noted below suggested by the rapporteurs.

1. Considering the fact that we have already developed a technology in hatchery construction and management, but the details of which are not available to the entrepreneurs, it is recommended that actions may be initiated to the technology transfer to the industry / entrepreneurs by bringing out brochures, leaflets and other extension material in the subject.

2. In view of the fact that the design requirements of the shrimp hatchery very with reference to the local conditions, facilities available, production capacity and other factors, the available designs of the hatcheries at various institutions may be considered and improvements may be brought out as more and more experience in the field is gained.

3. The economics of the hatchery management requires immediate attention. It is urged that the hatcheries already set up or being set up should make available the data so as to promote further establishment of hatcheries.

He expressed his opinion that the second part of the recommendation of 4th session would be very much appropriate to this session also. It was then adopted with the approval of the house.

As concluding remarks, Mr S. N. Rao said, increased knowledge both at basic and applied level is required in hatchery production of prawn seeds. The MPEDA, as a national organisation engaged in extension activities of shrimp farming, are really committed to this approach as prawn production through capture fisheries is declining in an alarming rate and prawn culture is only the immediate alternative method of augmenting the production. In this direction, an advanced centre for training state level officers, extension workers, private entrepreneurs is being set up at Vallarpadom near Cochin. He also said that MPEDA is in the process of executing a pilot project for developing a model prawn hatchery through the International Trade Centre Geneva. As a matter of fact, the MPEDA was the organisation which took the initiation to bring risk

management in prawn aquaculture under the purview of insurance agencies. It is his optimistic view that the symposium has generated more enthusiasm in the concerned people and they would work more intensively, and would have much better results to discuss when they meet next.

The plenary session came to an end with the vote of thanks by Dr. P. U. Verghese.

RECOMMENDATIONS

1. Proper assessment of shrimp seed resources and their seasonal abundance in various brackishwater environments of the country should be undertaken expeditiously.
2. Action may be taken for establishing 'seed banks' supported by prawn hatcheries in different maritime states.
3. Economically viable balanced and suitable compounded feed should be prepared for the larvae, and attempts to produce microencapsulated feed should be taken up immediately.
4. Intensive efforts should be made to investigate larval diseases and to evolve, precautionary measures to prevent infections in hatcheries. Methods to treat the infected larvae are to be evolved and popularised.
5. Considering the growing need and importance of shrimp seed production and brood stock development, dependable methods applicable for each species of cultivable shrimp should be developed and the technology evolved be transfered to the entrepreneurs through training programme.
6. There should be a consolidation of technique of hatchery production of seed along with cost, design and layout facilities, in order to make it easy for the developmental agencies, entrepreneurs and farmers to start shrimp seed production through hatcheries. O

INAUGURAL SESSION

Mr. S. N. Rao
Welcoming the delegates

Prof. Mathew Pylee
Delivering presidential address

Mr. Vayalar Ravi
Inaugurating the Symposium

Dr. E. G. Silas
Giving felicitations

Plate II

TECHNICAL SESSION I & II

Seated Left to Right:
Mr. A. G. Varghese
Mr. R. M. Rao
Dr. E. G. Silas
Dr. M. J. George

Mr. R. M Rao presenting lead paper

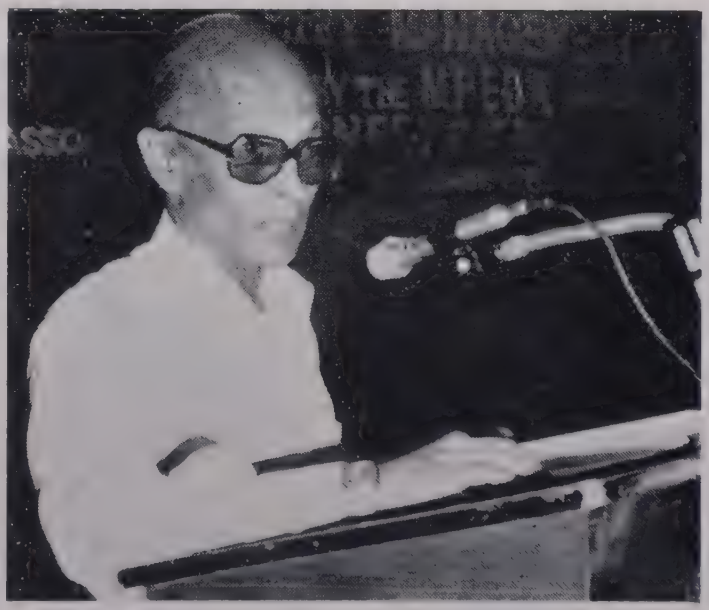
Dr. P. Vedavyasa Rao presenting lead paper

Seated Left to Right
Mr. V. Venkatesan
Dr. P. Vedavyasa Rao
Dr. M. J. Sebastian
Mr. B. Vishnu Bhat

TECHNICAL SESSION III & IV

Seated Left to Right :
Prof. D. V. Reddy, Mr. M. S. Muthu
Dr. C. T. Samuel, Mr. R. N. Padhi

Mr. M. S. Muthu presenting lead paper



Mr. K. H. Mohamed presenting lead paper

Seated Left to Right :
Mr. V. Krishnamurthy
Mr. K. H. Mohamed, Dr. V. D. Singh
Mr. K. Raman

Plate IV

TECHNICAL SESSION V & PLENARY SESSION

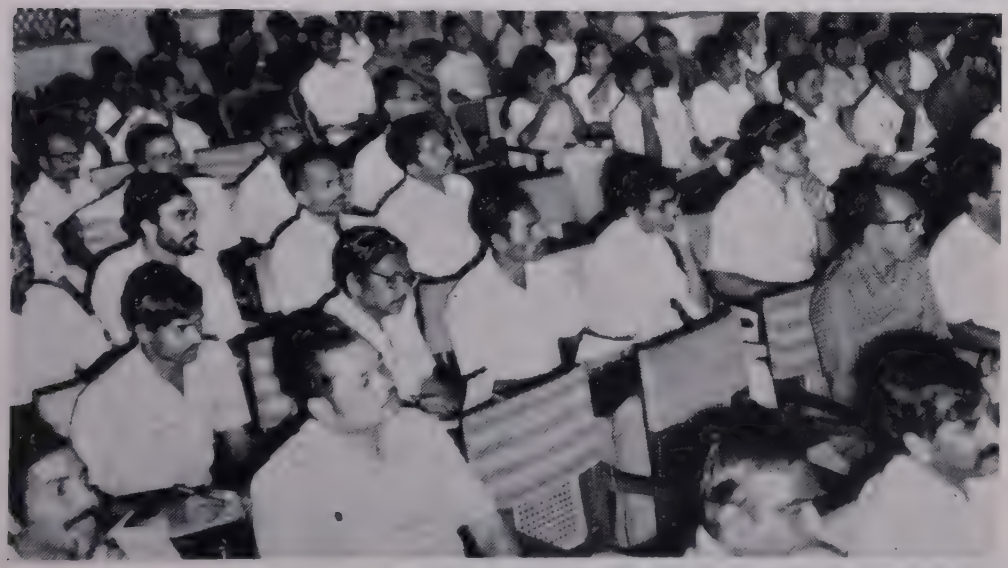
Seated Left to Right:
Mr. P. R. S. Thampi
Prof. D. V. Reddy
Mr. K. H. Alikunhi
Dr. J. Bojan

Prof. D. V. Reddy presenting lead paper

Dr. P. U. Verghese giving vote of thanks

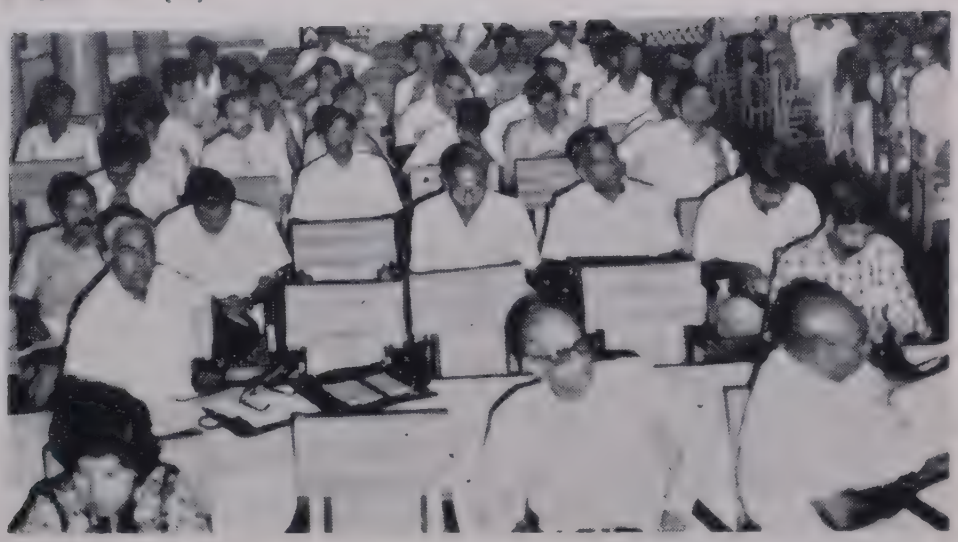
Seated Left to Right
Dr. G. Santhana Krishnan
Dr. V. D. Singh
Dr. E. G. Silas
Mr. S. N. Rao
Mr. K. H. Alikunhi
Dr. E. T. Samuel
Mr. R. Gamanathy

Plate V (a)



VIEWS
OF
THE
DELEGATES

Plate V (b)



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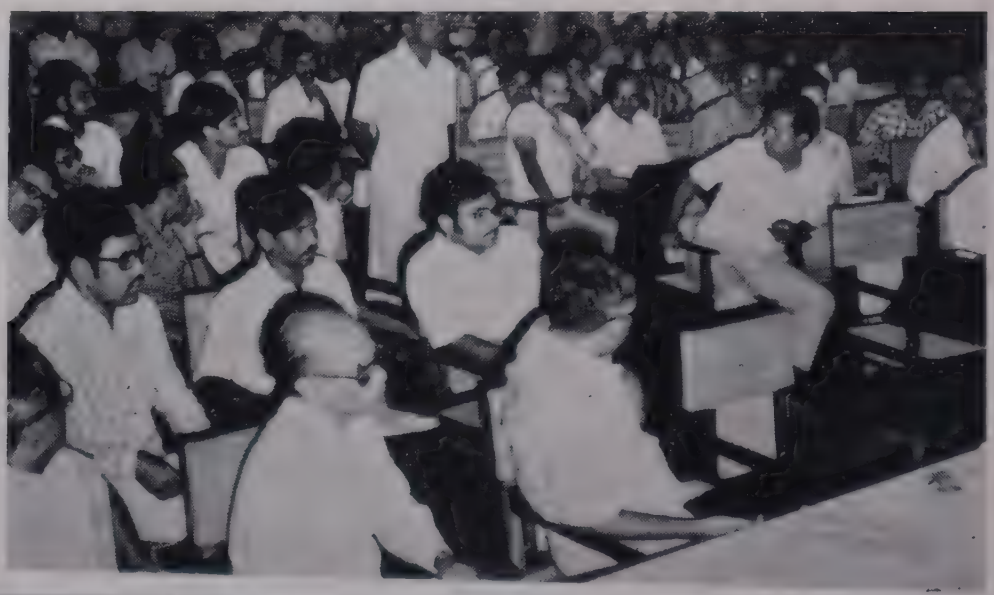
OF
THE
DELEGATES



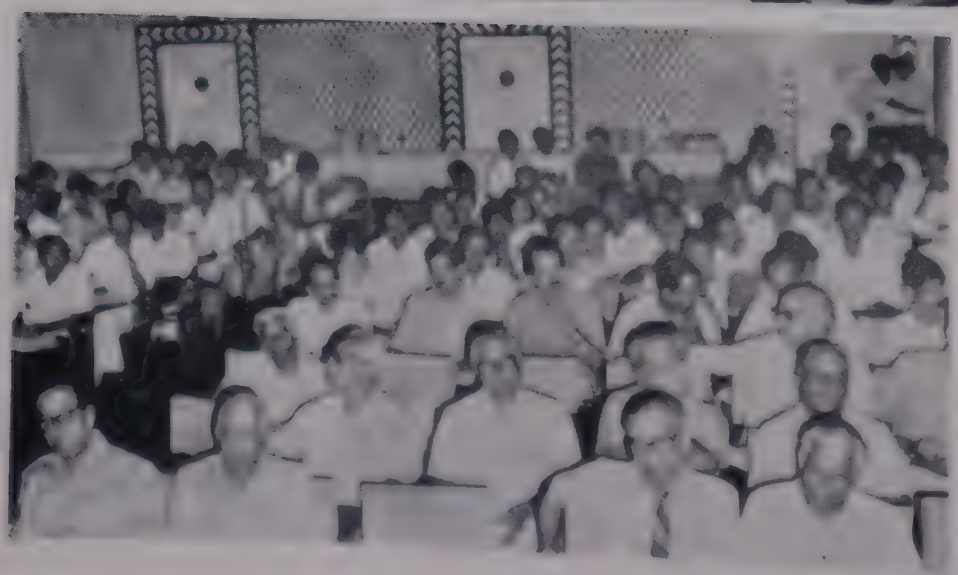
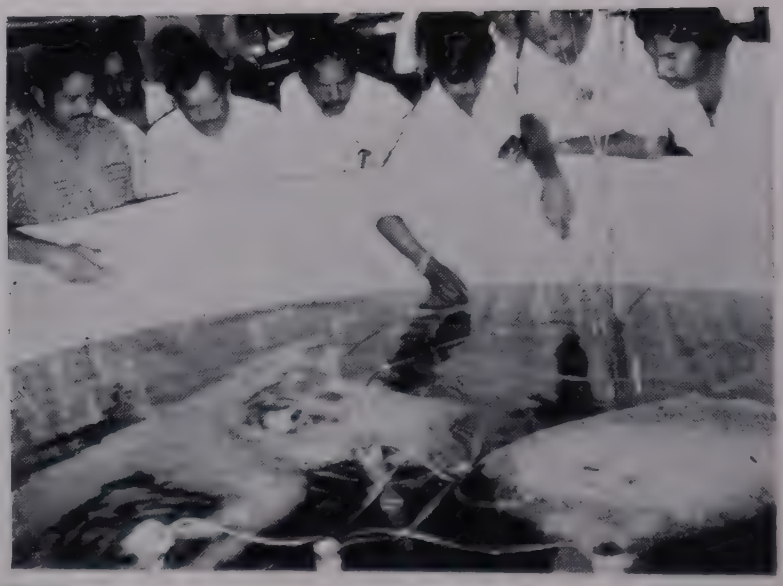


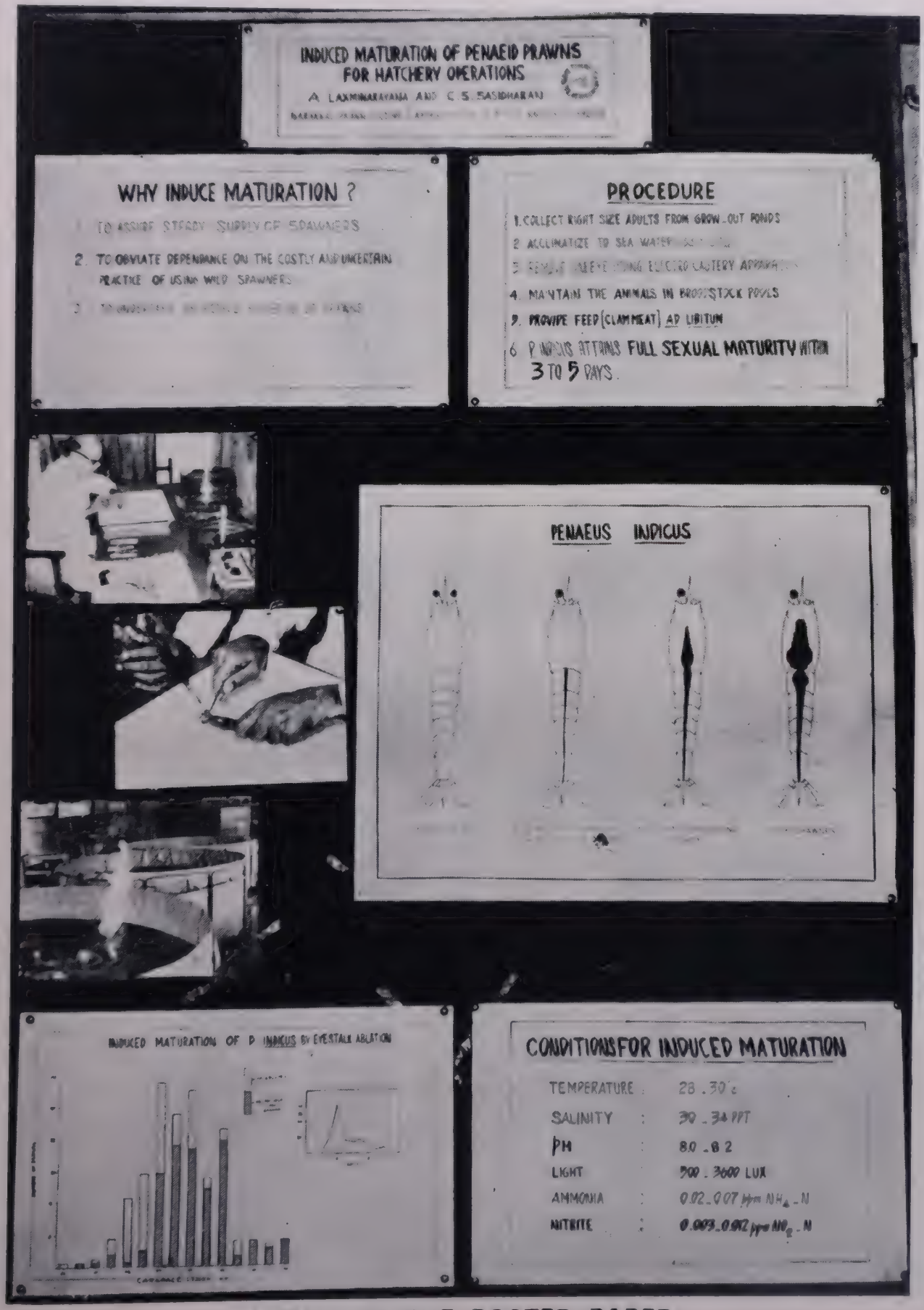
Plate VI (a)

Delegate's Field Visit
to Narakkal Prawn Culture
Laboratory (CMFRI)

Plate VI (b)

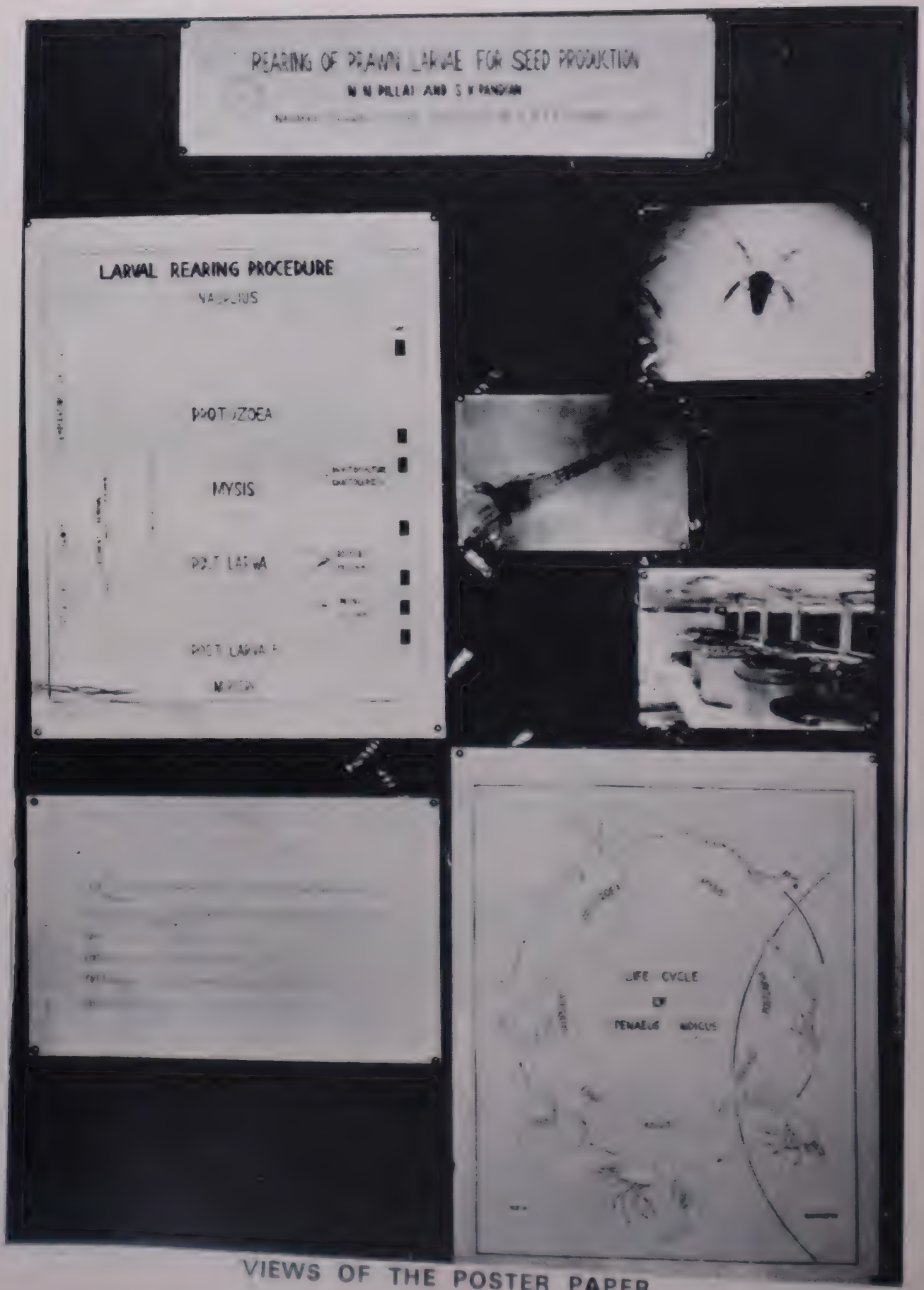


Delegate's Field Visit
to Narakkal Prawn Culture
Laboratory (CMFRI)



VIEWS OF THE POSTER PAPER

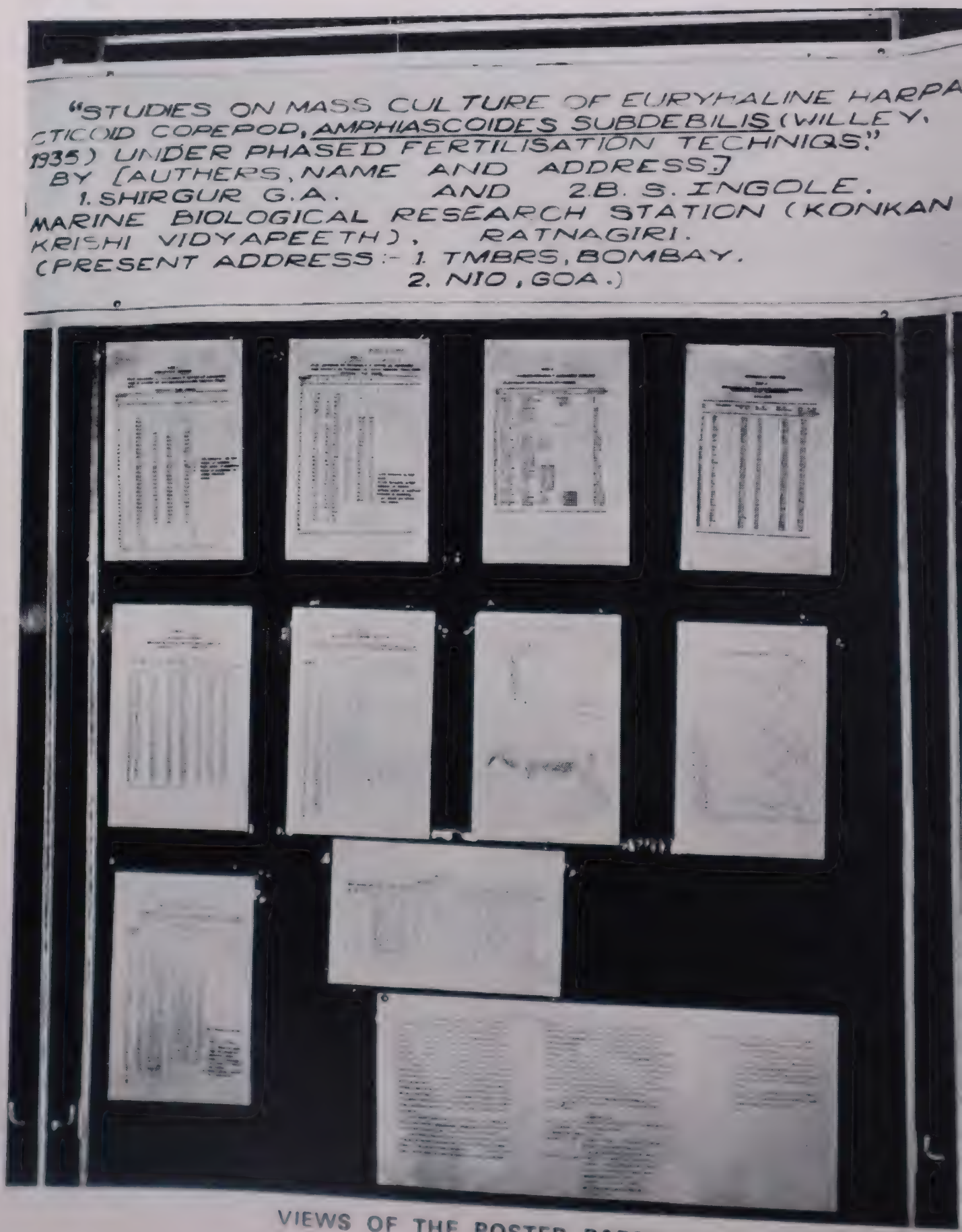
Plate VIII



VIEWS OF THE POSTER PAPER

VIEWS OF THE POSTER PAPER

Plate X



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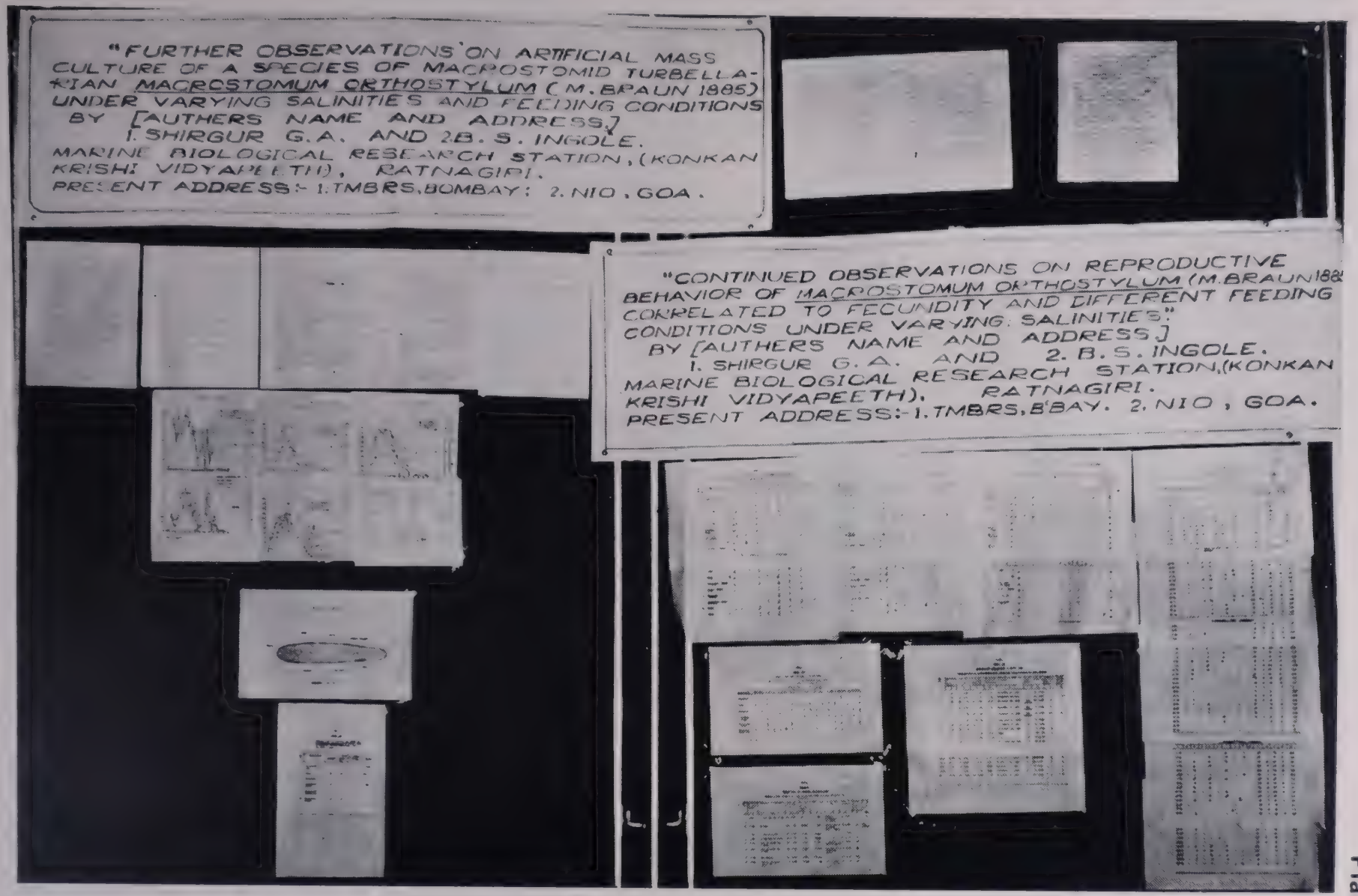
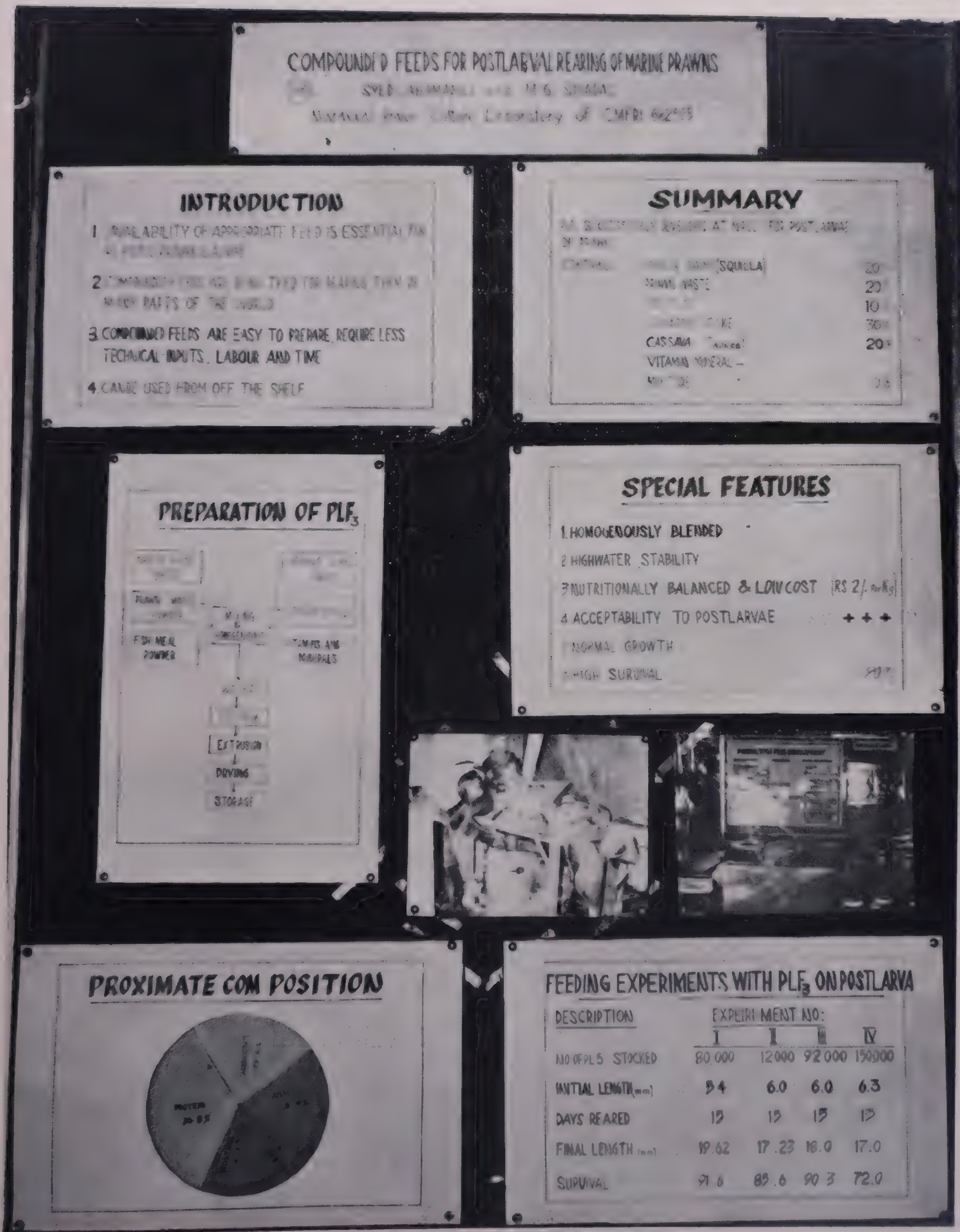


VIEWS OF THE POSTER PAPERS

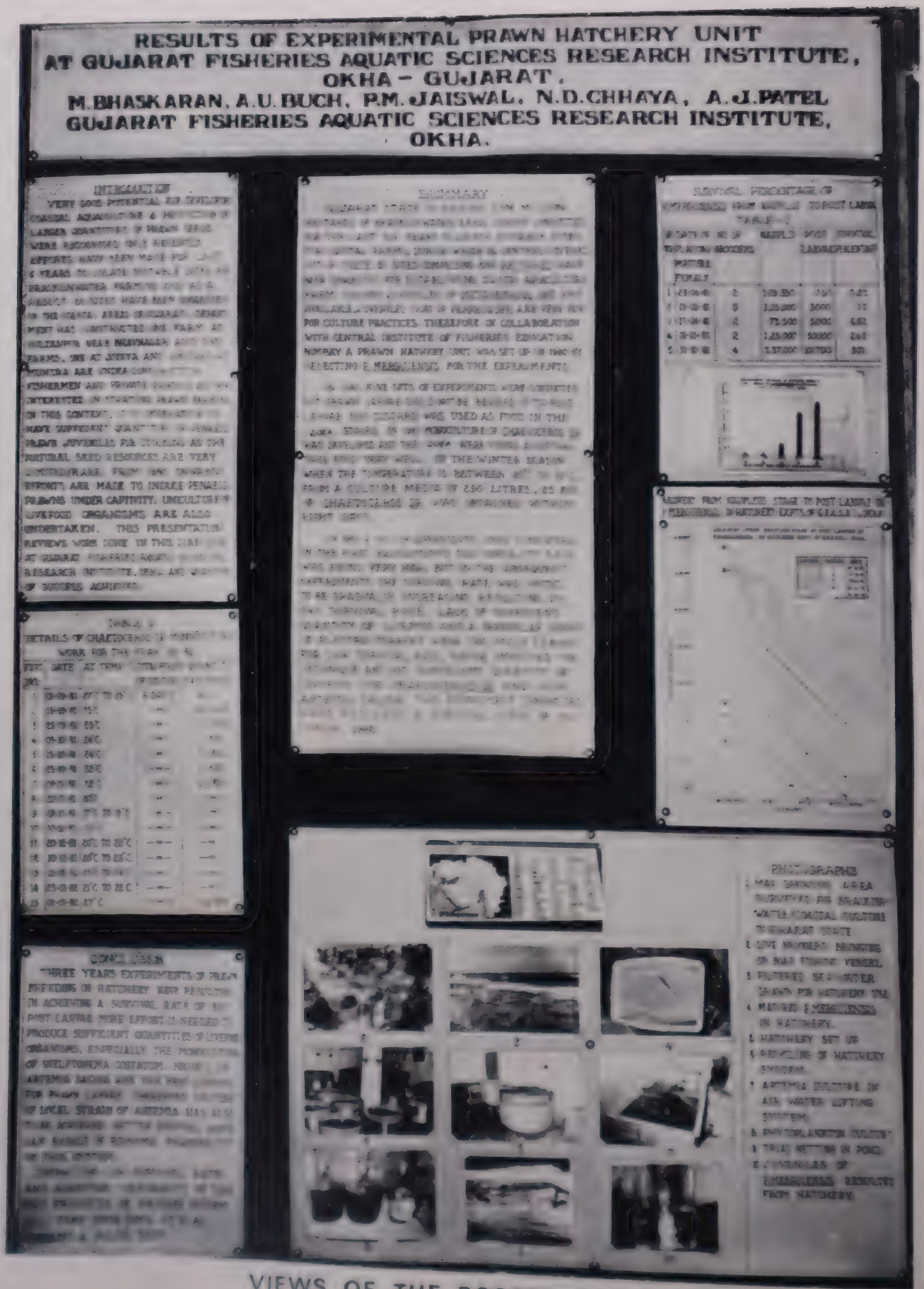
Plate XII

VIEWS OF THE POSTER PAPER



VIEWS OF THE POSTER PAPER

Plate XIV



VIEWS OF THE POSTER PAPER

SHRIMP SEED RESOURCES OF INDIA

R. MALLIKARJUNA RAO
Central Inland Fisheries Research Institute, Barrackpore

Introduction

Twentyseven species of shrimps belonging to Penaeidae occur in our coastal waters, of which eleven species are found to be suitable for culture due to high market prices, attractive sizes, growth and other biological factors. These (with maximum sizes in brackets) are *Penaeus monodon* (320 mm), *P. indicus* (230 mm), *P. semisulcatus* (250 mm), *P. merguiensis* (240 mm), *Metapenaeus monoceros* (180 mm), *M. affinis* (180 mm), *M. dobsoni* (125 mm), *M. brevicornis* (125 mm), *Parapenaeopsis stylifera* (140 mm), *P. sculptilis* (165 mm), and *P. hardwickii* (120 mm). Biology, breeding and fishery aspects of most of the species have been investigated in detail by several workers. Kunju (1978), Rajyalakshmi (1980) and Kurian and Sebastain (1982) have given taxonomical characters, growth and their suitability to culture. It is needless to stress the importance of culture of these species in view of the constantly increasing demand in the export market and saturated natural fisheries. Shrimp exports touched Rs. 212 crores in 1979–80. As such the market value of shrimps especially the *Penaeus* group have gone beyond the purchasing power of common man. Therefore, it is imperative to consider also the necessity of culture *Metapenaeus* and *Parapenaeopsis* group of shrimps in brackishwater farms for domestic consumption in view of their cheaper prices.

India is foremost in the world shrimp production, but there appears to be a declining trend recently. While the production in 1977 was 232.1 thousand tonnes, it came down to 143.9 thousand tonnes and 182.1 thousand tonnes in the subsequent years. Its contribution in the total world production varied between 8.73 to 11.97% during 1976-79 (FAO. 1979). Shrimp production in the west coast is about 80% while the rest is from the east coast. Average composition of individual shrimps in the total production in the country (Banerjee, 1969) is – *Metapenaeus dobsoni* 33.81%; *Parapenaeopsis stylifera* 17.11%; *Penaeus indicus* 11.68%; *Metapenaeus affinis* 9.66%; *M. brevicornis* 6.89%; *M. monoceros* 4.4%; *P. hardwickii* 3.62%; *P. monodon* 2.78%; *P. sculptilis* 2.52% and *P. semisulcatus* 1%. Relative abundance in different zones is given by Mohamed (1973).

Prawn and shrimp production in some of the estuaries and brackishwater lakes of east coast of India have been investigated by Central Inland Fisheries Research Institute. In the Hoogly-Matlah, estuarine system, the production varied between 857 to 1,049 t. during 1964-66.

The dominant penaeid shrimps are *M. brevicornis, P. sculptilis* but *P. indicus* and *P. monodon* also occur in limited quantities. In the Chilka lake the fishery fluctuated between 548 to 1,863 t. during 1957–65 with *P. indicus, P. monodon, M. monoceros* and *M. dobsoni.* In the Godavari estuary, the prawn fishery is around 2,700 t. consisting of *P. indicus, P. monodon, M. monoceros* and *M. affinis.* In the Pulicat lake the prawn production is from 378 to 635 t. (1966–70) comprising *P. indicus, M. monoceros, M. dobsoni, P. semisulcatus* and *P. monodon.*

Larval identification

Larval and post-larval stages of important shrimps have been described by Menon (1937, 1951), Mohamed *et al.* (1968), Rao (1973), George (1973) and the field identification characteristics of post-larvae and juveniles were investigated by Rao and Gopalakrishnan (1969), Raje and Ranade (1972), Muthu and Rao (1973), Rao (1976) and Muthu (1978). Review of the post-larval and juvenile identification of all the important cultivable shrimp species describing rostral characteristics, colouration and swimming behaviour for the easy identification in the field is given by Rajyalakshmi (1980).

The developmental stages in penaeids include nauplius (6 stages), protozoea (3 stages) and mysis (3 stages). The nauplius stages do not feed and subsist on the reserve yolk and protozoeal stages start feeding on diatoms while the mysis stages start consuming larvae of zooplankters in addition. The mysis stages lose their planktonic habit as they transform into post-larval stages which settles down and develop crawling habit.

Seed Prospecting

The seed of quality prawns is the prime requisite in organising large scale shrimp farming operations in the country. All the penaeid prawns breed in the offshore waters at different depths and the larval and post-larval stages enter the lagoons, creeks, estuaries and brackishwaters along the coasts as part of planktonic mass migration. These estuarine areas are suitable nurseries offering the required ecological niches for their growth. The prospecting of larvae to juveniles in these nursery areas is engaging considerable attention for taxonomic studies, forecasting fishery and for procurement of seed for aquaculture. Blanco (1972) has briefly summarized the seed procurement in the Indo-Pacific region. The assessment of seed resources in the estuaries, brackishwater lakes, lagoons, creeks, etc., in different regions of India are generally done by the operation of tow net, shooting net, drag net and cast net. Seed prospecting has been carried out in the mouths of Hoogly, Kulti and Roopnarayan estuaries of the Hoogly–Matlah estuarine system (Gopalakrishnan and Rao, 1968), Subramanyam and Rao, 1970; Chakraborthi *et al.*, 1982), Chilka lake (Jhingran and Natarajan, 1969, Ramakrishnayya, 1979), Pulicat lake (Subramanyam and Rao, 1968; Rao and Gopalakrishnayya, 1974; Rao and Gopinath, 1975; Gopinath *et al.*, 1974), Vellar estuary (Subramanian, 1978), Adayar estuary (Bose *et al.*, 1978) and Godavari estuary (Subrahmanyam and Ganapathi, 1971) on the east coast and in the backwaters and estuarine mouths of Kerala (George, 1963; Mohamed *et al.*, 1968; Rao, 1973, Muthu and Rao, 1973; Kuttyamma, 1975), Kayamkulam lake (Kuttyamma

and Kurian 1978), Korapuzha estuary (Menon, 1980) and around Goa (Achuthan Kutty *et al.*, 1971, Achuthan Kutty and Nair, 1980; George and Goswami, 1978; and Selvakumar *et al.*, 1977). Information is lacking from Mahanadi estuary, Collair lake on the east coast and Maharashtra, Karnataka and Gujarat on the west coast. Locations of collection centres in different parts of the country are depicted in figure 1. Some of the recent works done at the Central Inland Fisheries Research Institute have brought in the concept of catch/net/hour using a standardised Midnapore shooting net uniformly to project the relative abundance of seed available in the Hoogly estuary incorporating the calenders of availability of penaeid shrimp seed. Since its inception, the All India Co-ordinated Research Project on Brackishwater fish farming is engaged in prospecting shrimp seed in 5 different states of the country namely at Kakdwip (West Bengal), Keshpur (Orissa), Kakinada (Andhra Pradesh), Adayar and Marakanam (Tamil Nadu), Vyttila (Kerala) and Panaji (Goa). Important seed calenders for the Hooghly-Matlah estuarine system (Gopalakrishnan *et al.*, 1975, Bhanot, 1972) and Co-ordinated Project Centres (Anon, 1981) are incorporated in Table 1 and 2 which give details of months of availability, peaks and catch/net/hour of some species. They depict the picture of the relative abundance and help to draw comparisons which is the first step to assess the total quantity of seed available from a particular source. From the present knowledge on the seed prospecting from different sources, it would be difficult to quantify the seed availability in the country which depends on several factors.

Commercial Seed Collection Techniques

Collection techniques are mostly based on traditional methods by flooding embanked shallow areas with tidal waters during the peak seasons of availability in West Bengal and Kerala backwaters. In tidal creeks and canals with water current fixed shooting nets of Midnapore type or fyke nets are preferable. Other nets described are enclosure nets suitable for operation in areas having large tidal amplitude and hapa, scoopnets or even cast nets can be operated in inundated waters at high tides particularly when the shrimp develop the crawling habit and avoid shooting nets, that filters only surface waters and settle down on grassy vegetation. Bush fishing is also adopted to lure the seed to accumulate near the installed disintegrating vegetable matter for easy capture. Various types of gears, their designs and operational procedures have been described by Jhingran *et al.* (1970) and Rajyalakshmi (1982). Alikunhi (1980) has stressed the urgency of organising the seed industry as the first step to shrimp farming by training the local interested farmers in the collection techniques, handling, segregation and storage of shrimp seed and involving the Panchayats in the procurement and distribution to pond operators. Approximately 10,000 post-larvae can be collected per net/tide by the operation of one shooting net and in potential areas 20,000 to 25,000 fry/net/hour in peak periods like April-May in the Muriganga estuary in West Bengal (Verghese, 1978) can be collected and segregated. Economic potentialities of seed collection has not been worked

out for different gears employed. Ghosh (1976) has estimated a net profit of Rs. 302 per month for one shooting net. Dwivedi (1981) has reported the establishment of a seed bank in Kakinada, selling *P. monodon* fry at Rs. 60-80 per thousand and also one in Tamil Nadu. Rajyalakshmi (1980) has recorded the existence of seed industry at small village or household level in West Bengal for *P. monodon* fry which are sold at Rs. 12–16 per thousand fry in peak seasons and Rs. 25–30 per thousand fry in off seasons.

In Philippines and Indonesia collection of shrimp fry from natural resources is a well organised industry. In Philippines, *P. monodon* (Sugpo) fry are caught by hand nets or lures which comprise aquatic plants called *bon-bon (Papsalum veginatum)* tied to ropes at intervals and suspended by poles. The fry are attracted and cling to these plants which are collected in hand nets by lifting and shaking the post-larvae in hand nets. These are transferred to jars for distribution to pond operators. Species are sorted out before introducing them into nurseries. In Indonesia, large fixed nets are used in brackishwater creeks connected to the sea for collecting post-larvae for stocking purposes. In Indonesia alone, the seed industry provides employment to 10,000 people in procuring 400 million *P. monodon* fry annually.

Seed Segregation

By manual methods it is possible to segregate 32,000 post-larvae of *P. monodon* fry in 90 man-hours or 355 per hour at Central Inland Fisheries Research Institute which is time consuming. However, preliminary work carried out indicates the possibility of usage of anaesthetics in the segregation of different penaeid post-larvae. Chakraborti *et al.*, (1977) could observe species stratification of penaeids and palaemonids by treating 1 ml of tertiary amyl alcohol per litre of medium and in 5 to 8 minutes 80% decantation contained 60–80% of *Penaeus indicus* and *M. monoceros* and the remaining 20% contained mostly *P. monodon* upto 93% which were kept later for observation for one hour in fresh river water for successful survival. This has been attributed to differential tolerance capacity of prawn species to anaesthetics. Further work in these lines with different chemicals and sedatives will go a long way in the commercial segregation of shrimp seed from natural sources saving time, handling mortality and man-power.

Seed Transport

De and Subramanyam (1975) and De (1977), have done work on the short distance transport of *P. monodon* and *P. indicus* under oxygen packing after conditioning the seed for two to three hours and concluded that 200 seeds per litre can be transported for a duration of 12 hours and 150 seed for 20 hours involving 15% mortality. However, it was found that *P. indicus* seed was more delicate. Mammen *et al.*, (1980) reported the transport of fry in milk can like containers on board without any difficulty. In the air transport of *P. monodon* from Calcutta to Cochin involving 18 hours of transport (including 12 hours waiting at Madras) survival from 45 to 96% were obtained when fry were packed from 250 to 2,000 per 18 litre tin. They have noted

mortality because of cannibalistic tendencies at the time of storage and transport. This can be minimised if adequate live food like *Artemia* nauplii are also incorporated as in Thailand. Keeping adequate weeds or preferably inert artificial plastic weeds during storage and in open containers in short distance transport thereby providing shelter will reduce mortalities. Banerjee *et al.* (1979) have estimated oxygen requirement of *P. monodon* fry during transport. 194 mg and 385.5 mg per thousand fry of oxygen is required for 12 and 24 hours respectively. Fry required 0.0162 mg/fry/hr while juveniles (48-52 mm) required more oxygen in the range of 0.25 to 0.48 mg/fry/hr. More detailed work is necessary on all the available species of shrimps in the country. Air-conditioned transport with aeration facilities may also be tried after evaluating the economics.

Of the many chemical parameters needing monitoring during collection, segregation, transport and acclimation while stocking, salinity of the water medium is the most vital factor needing estimation and whose fluctuations prove fatal. The titration methos of salinity is time consuming and cumbersome in the field and needs to be replaced by the usage of refractometers either imported or manufactured in the country.

Factors Influencing Abundance

Availability and abundance of the post-larval penaeids have been related to several ecological and meteorological variables such as salinity, temperature, river discharges, rains, current, depth, substratum, suspended matter, plankton, seasons, lunar and diurnal cycles, mangroves, mud banks and pollution (George, 1962, 1963; Subramanyam, 1967; Jhingran and Natarajan, 1969; Rao, 1972; Rao and Gopalakrishnayya, 1974 and Gopinath *et al.*, 1974). In Chilka lake two major peaks of juvenile abundance of *P. mondon* and *P. indicus* as major waves in April–July and August–December are noticed. These juvenile waves were further traceable to the preceding post-larval peaks (during January–March and April–July periods) and the success of fishery (Jhingran and Natarajan, 1969, 1973). Correlations of larval abundance and fishery have also been made in Pulicat, Godavari, Cochin and Goa waters. In several accounts, salinity and temperature have been related to the larval peaks and critical limits for each species have been indicated. *P. monodon* and *M. monoceros* have slightly wider tolerance to salinity than other penaeids. Subrahmanyam and Rao (1968) observed the occurance of *Penaeus* spp. to be more during night time in Pulicat lake. Ramakrishnayya (1979) observed similarly for *Metapenaeus* spp. in Chilka lake but could not get clear indications for *Penaeus* spp. Post-larval incursions were rich both during full moon and new moon days (Subrahmanyam and Ganapati, 1971) in Godavari estuary with more pronounced recruitment during full moon day. In Matlah estuary (Bhanot, 1971) *P. indicus* was in greater abundance during the full moon than the new moon while it was reverse for *M. brevicornis* and seed collections made at high tides were richer especially at 2–4 m depth. Kuttyamma and Kurian (1978) observed higher abundance in high tides, moon phases and night time. Chakraborti *et al.*

(1982) studied the hourly abundance of post larvae of *P. monodon* and *P. indicus* and concluded the existence of direct relationship between volume and salinity of water and larval abundance. Gopinath (1978) observed more number of *P. indicus, M. monoceros* and *M. dobsoni* at the lake mouth while *P. monodon* and *P. semisulcatus* were more on the sides in the *Pulicat* lake. Rao and Gopinath (1976) further observed that generally in shooting net collections, seed was more in sides than the centre of the lake. Ramakrishnayya (1979) observed more in the mid channel than sides of Chilka lake mouth. Subramaniyan *et. al.* (1978) related the abundance of *P. semisulcatus* seed with mangrove grass beds in Vellar estuary. From all these, considering the collection aspects, it appears that generally penaeid post-larval abundance will be greater during high tides, night times and moon days. More detailed studies on all the variables in relation to species abundance are needed to make generalisations.

From the examination of the availale literature, it can broadly be inferred that among *Penaeus* group *P. indicus* and *P. monodon* are obtained through out the country round the year of which *P. indicus* is more dominant. *P. merguiensis* has a wider distribution on the west coast (except Kerala) than the east coast, while *P. semisulcatus* is mostly from Tamil Nadu and Andhra Pradesh. Among *Metapenaeus* group, *M. monoceros* is available throughout the coastal waters of the country, while *M. dobsoni* is distributed in abundance mostly in the west coast of Kerala, Goa and Karnataka. *M. brevicornis* is mostly limited to west Bengal and Gulf of Kutch, and *M. affinis* to Kerala. The different species contribute sizeably to the availability in the areas of their occurance.

Seasonal abundance

The species-wise account is given and they may have annual variations in seasons due to various ecological factors (Table 3).

Penaeus monodon

The post-larvae are available throughout the year from the tidal zones of Hooghly estuary with two peaks in March-June and November. Along Chilka lake the period of abundance is January-April and August - November. Other potential areas are Mahanadi estuary, Godavari estuary, Kakinada coast, Adayar estuary, Ennore backwaters and mouth of Pulicat lake. Goa and Kerala have also areas with lower density.

P. indicus

The post-larvae and juveniles are recorded to be available all along our coastal waters, estuaries, etc., in our country. In Hoogly-Matlah estuarine system and Pulicat lake the seasons are January, March and August. In Chilka lake it is April-July and August-November. These are also reported to contribute a major share in Kakinada Bay and backwaters of Kerala.

P. merguiensis

This species is reported from Kakinada Bay in the backwaters and creeks and come in mixed catches with *P. indicus* and in the mangrove swamps of Goa.

P. semisulcatus

Seed of this species is more abundant in the estuaries and lagoons of coastal Andhra Predesh and Tamil Nadu (Kovalam). Also recorded in Pulicat and Chilka Lakes.

Metapenaeus monoceros

Post-larvae are reported to be occurring most abundantly in coastal waters throughout the country particularly in Adayar estuary, Pulicat lake and Gautami-Godavari estuary. However, its magnitudes is less in Hoogly, backwaters of Kerala and Chilka.

M. brevicornis

This species is one of the most abundant commercial species in juvenile phase in the Hooghly estuary. Mysis and post-larval stages are encountered year round except July-October. The seed is also reported to occur in Godavari estuary, Kakinada Bay, Gulf of Kutch and Goa.

M. dobsoni

This is the most abundant species in the backwaters and lagoons along Kerala coast. The seed is by far the most abundant of all the prawns in this region and occur almost throughout the year. It is also reported to occur from chilka and Pulicat lakes and to a lesser extent in the Godavari estuary. Seed is available over a major part of the year with peaks during January - June and October.

Parapenaeopsis sculptilis

Juveniles are available throughout the year in the tidal zones, of Hooghly-Matlah estuarine system, peaks being March-June and in November. In Godavari estuary and Kakinada Bay seed is available during November to January.

P. stylifera

This species is fairly abundant in the marine plankton of Kerala during monsoon months.

General account of the availabilty of different species in the country is given by Rao (1978) and Rajyalakshmi (1980).

Areas of Cultivation

The 5,600 km coast line of the country has many brackishwater areas requiring reclamation for aquaculture development. According to National Commission on Agriculture (1976), these potential areas amount to 1.42 ha in different States. At present wild culture of shrimps is in vogue in the bheries of West Bengal in about 9,000 ha with shrimp yields consisting of *P. monodon, P. indicus, M. monoceros,* etc. Besides, in about 4,500 ha in Kerala are under paddy-cum-fish culture (Pokkali fields) with shrimp yields consisting of *P. indicus, M. dobsoni, M. affinis,* and *M. monoceros*. The total area under cultivation, as per the recent literature, is about 30,000 ha in the country (West Bengal, 20,000 ha; Kerala 5,117 ha; Karnataka 4,800 ha; Gujarat 88 ha) (Rao, 1978). Figures are not available in respect of Tamil Nadu, Andhra Pradesh, Orissa and Goa where shrimps are cultured in a very limited scale.

Present status and Future Requirement of Shrimp Seed

For lack of proper statistical surveys and analyses, quantification of either the

seed requirement or the seed availability from all the natural resources in the country are exactly not known. However, Rao (1978) has made an approximate estimate of the seed requirement of the cultivated waters in the country to be 5237.5 M for intensive shrimp farming. Apart from the technological advances made in the country recently financial and other implications have to be seriously considered to convert the present traditional brackishwater farming operations into intensive shrimp farming under scientific management.

Brackishwater fish and shrimp farming technologies have been developed recently at CIFRI. For stocking juveniles (50–60 mm)/ha in the growout ponds, an allowance of 15% for transit between nursery and culture ponds, 60% in the nursery phase and 15% for transit from procurement centre to nurseries are reasonable from the existing knowledge and experience. Hence, at the minimum recommended stocking rate of 20,000 juveniles per ha for intensive shrimp farming and 4,000 juveniles per ha for polyculture, at least 70,000 and 14,000 post larvae (10–15 mm) per hectare respectively are required at the procurement/production centres. It is possible to raise 3 crops under intensive culture and at least 2 crops under polyculture. Aquaculture development has to go in phases by different states in the country in three facets namely shrimp culture, polyculture and fish culture. For an initial development plan by different States to bring 10,000 ha for shrimp culture and 5,000 ha for polyculture it would require multidepartmental approach besides funding, infrastructure, inputs, transfer of technology, trained manpower and the required seed. The seed requirement for 3 crops in intensive shrimp culture and 2 crops of shrimps in polyculture for 15,000 ha is projected in Figure 2 which works out to be 224 crores for the first phase of aquaculture development.

Limitations and Problems of Commercial Collection of seed

The estimated requirement of shrimp seed for aquaculture development in the country being huge, there are inherent limitations to the depenence of shrimp seed from natural resources alone. Seed prospecting has not been thoroughly done on an organised basis on an All-India level to project the exact potentialities and requirements. Seed availability depends on several ecological factors, vagaries of nature, pollution, breeding success, recruitment, accessibilty and lack of organised seed collection and distribution industry and hence may vary with years, seasons and locations. Also the mixed collections may not consistantly contain high percentages of quality seed. Mortality of seed may also occur due to cannibalism, changes in water qualities, predation by fishes, handling and logistic problems in the process from collection to stocking. The recent declining trend in the marine landings and catch per unit of effort (Swaminathan, 1978) clearly indicate the fishing pressure in our coastal waters. There might be a threat in the near future for overfishing in our off-shore waters which are the ideal spawning grounds of shrimps thereby affecting the breeding success and recruitment and finally decline in seed abundance from natural sources. The countless fishing devices in lake mouths and siltation problems as

in Chilka might disturb the shrimp migrations. Further, from the available information, we might not get the full seed requirement from nature. Hence, reliance cannot be based fully on procurement, and thus there is the urgent need to supplement the seed by hatchery operations. Countries like Japan are not only self sufficient in seed production of *Penaeus japonicus* from hatcheries but also going for open water stocking in bays to supplement their fishery (Kurata and Shigueno, 1976).

Future Approah

Role of hatcheries: In India, studies on life cycles of most of the shrimps have been completed and experimental production of post-larvae in small plastic containers under laboratory conditions have recently been achieved in respect of *P. monodon, P. indicus, P. merguiensis, M. brevicornis, M. affinis, M. monoceros* and *Parapenaeopsis stylifera* (Muthu 1978; Hameed Ali, 1978). In the experiments conducted at CIFRI maturation and breeding of *P. monodon* has been achieved in pond environmentat Kakdwip Research Centre (Halder, 1978) and in bheries at Sandeshkhali, West Bengal and of *P. merguiensis* at Puri Centre. In Narakkal Centre of CMFRI impregnated prawns from trawl catches are spawned in 50 l. plastic containers. Zoeal stages were fed with locally collected phytoplankters such as *Thalassiosira, Navicula, Pleurosigma* and *Nitzchia*. Mysis stages were fed with larvae of rotifers and copepods, *Artemia* nauplii and *Brachionus*. Other items of feed tried are the suitably processed *Acetes* and *Mysopodopsis* spp. by CIFE.

In the other Asian countries such as Philippines and Thailand, stock cultures of phytoplankton are regularly maintained that are scaled up for mass culture in concrete tanks for feeding, when the cultures are in exponential growth phases, to various larval stages. Early zoeal stages are fed with *Chaetoceros* sp. and late zoeal stages and early mysis stages are fed with *Tetraselmis,* while the late mysis stages and subsequent Post larval stages are fed with *Brachionus* and *Artemia* nauplii. Other feeds like clam-meat, mysids, *Moina* and microencapsulated diet of egg are also tried. In the Japanese system for mass production of seed group spawning upto 20 spawners is done in bigger tanks (40–200 t. capacity) with initially 1 m depth and adding daily 10 cm of fresh sea water filtered through 150 μ filters. Fertilizers (KNO_3–3 ppm and Na_2HPO_4 – 0.3 ppm) are put daily upto P_5 stages. On the second day, diatoms are added for blooming and as a ready food for the transformed nauplii. Diatom counts are maintained at 5 to 10^4 / ml. *Brachionus* and *Artemia* nauplii are fed from Z_3 onwards. In 4 to 5 days water level will be full when the larvae attain mysis stages and the water is changed daily by one-third. In about 10-12 days postlarvae (P_5) at 50-100 / l are obtained which are collected by draining out the water and transferred to nurseries. With the progress made in the experimental seed production in the country, Alikunhi (1978) has suggested that a model hatchery of Japanese type using fertilisation system with a production capacity of 100 M. post-larvae annualy be established. Such establishments need proper site selection, broodstock sources, infrastructure facilities like 60-100t. tanks, water pumps, blowers, filters etc. and also a few diatom

culture tanks. Trained technicians to monitor water quality, feeding and other aspects such as nutrition, feed formulation and sanitation are very much essential. Such complexes need to be established at least one in each maritime state in the near future.

Artemia farming: Artemia farming needs to be started on Pilot scale to meet the anticipated basic requirement of the hatcheries in suitable locations by converting salt pans in some of the maritime States. This would reduce the problem of live food for shrimp and fish larvae in general.

Organising Seed Prospecting industry: There is an urgent need to organise the seed prospecting by the different States concerned with the task of preparing the seed calenders of potential sites. At the same time, farmers need to be trained in the collection and transportation techniques. Cooperatives and fishery corporation can actively participate in organising the seed industry by giving incentives, subsidies or free supplies of gears, containers etc. to farmers and acting as an intermediary between procurement and distribution of seed to pond operators.

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Fig. 1 Areas prospected for shrimp seed in the country.

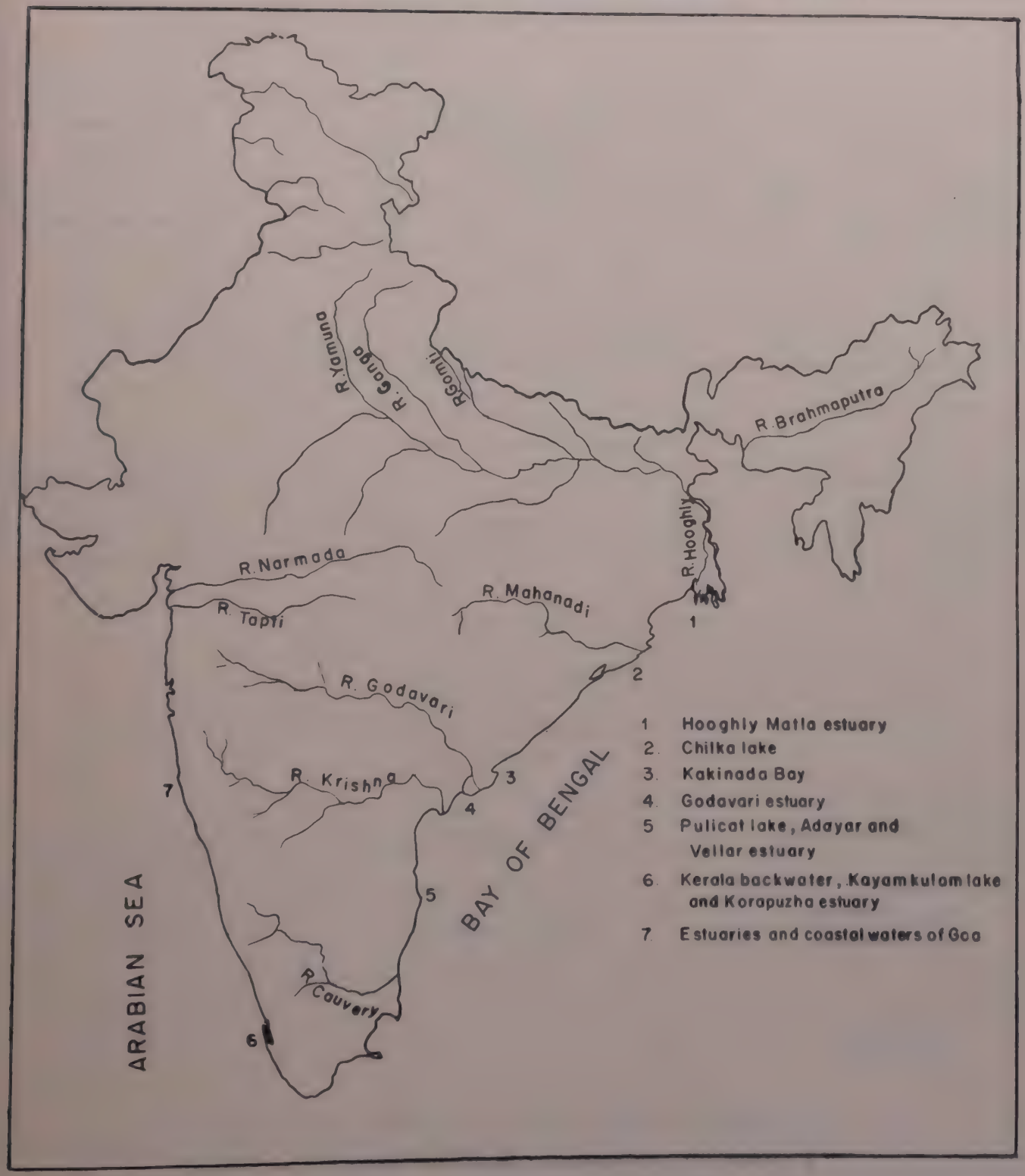
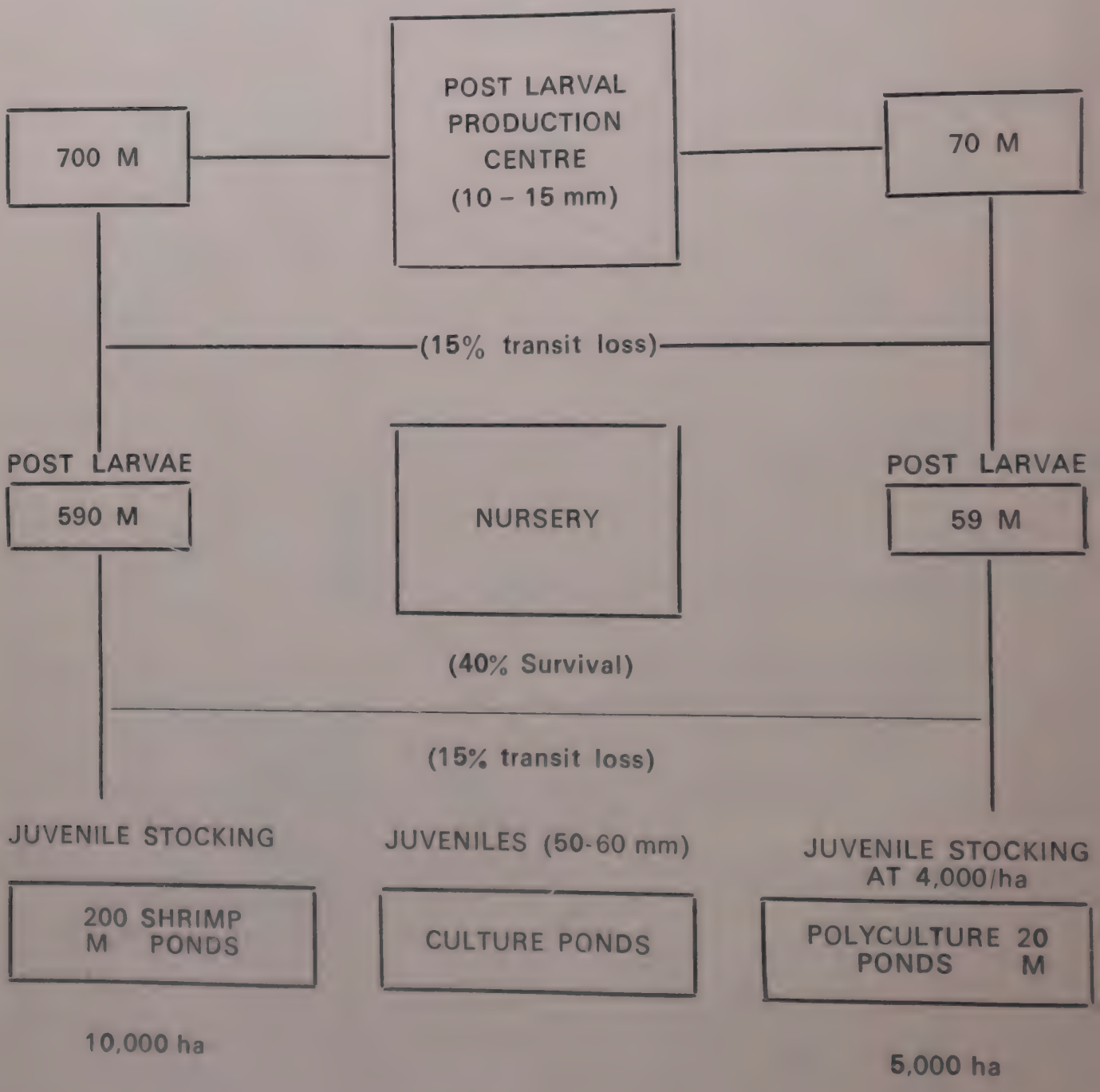


Fig. 2 : Per crop postlarval and juvenile requirement at full development of 15,000 ha of brackishwater area



3 crops for shrimp ponds = 700 M x 3 = 2100 M
2 crops for polyculture ponds = 70 M x 2 = 140 M
Total seed requirement = 2240 M

Table I

Shrimp seed calender for the

Hooghly - Matlah estuarine system

Species		Hooghly	Matlah	Thakuran	Gosaba	Ichhamati
Penaeus monodon	a.	2–10	1–3, 6–9	4–8	5–9	5–7
	b.	20–1766	10–165, 10–25	48–660	30–109	29–130
	c.	2–4,7	3,7	7,8	7,8	6
	d.	154–1766, 80–803	55–165, 10–25	426–660	50–109	60–130
Penaeus indicus	a.	1–10	1–4, 6–12	2–10	2–8	5–12
	b.	100–5566	12–88, 2–15	80–328	60–352	2–180
	c.	2–4, 8	3,9	4–5, 7–8	6,7	4,5
	d.	1671–5566, 13907	74–88, 8–15	110–328	160–352	88–180

a = months of availability indicated as 1–12 for January to December.

b = Range of catch/net/hour

c = Peak months of availability

d = Range of of catch/net/hour

Table II: Shrimp seed calenders as prospected by the All-India Coordinated Research Project on Brackishwater Fish Farming (Nov. 78-Sept. 81)

Species		West Bengal	Orissa	A. pradesh	Tamil Nadu		Kerala	Goa
		Kakdwip Centre	Keshpur Centre	Kakinada Centre	Adayar Centre	Marakanam Centre	Vytilla Centre	Panaji Centre
P. monodon	a.	1-12	1-12	1-12	3-5, 9-12	1-12	1-4	5-7
	b.	17-1152	200-4600	1-575	142-472, 12-280	2-372	368-635 Near Cochin bar mouth	2
	c.	4-7, 9-10	1, 4-5, 8-9	6-9	4-5, 9, 12	3-5, 9,12	4	–
	d.	501-1152 199-283	800-850 1020-5600	575, 71	470,226, 280	148-372 218, 142	635	–
P. indicus	a.	1-12	1-2, 4-12	1-12	1-5, 9-12	1-12	9-12, 1-3 Near Cochin bar mouth	10-12 1-5
	b.	9-3022	200-6224	3-2834	40-11565 2670-11500	—	617-2240	24-286
	c.	2-3	4, 7-9	5, 6	1-2 11565	7-9, 12-1 3240-6860	–	12-4
	d.	2522-3022	4000-6224	618-2834	8600-11500	11725-14800	–	286,168

a = months of availability indicated as 1-12 for January-December
b = Range of catch/net/hr
c = Peak month of availability
d = Range of catch/net/hr.

Table III. Distribution of shrimp seed in the country

Species	State	Season of abundance
P. indicus	Gujarat	February-April
	Goa	February-May
	Karnataka	December-January
	Kerala	October-May
	Tamil Nadu	February-May
		August-September
	Andhra Pradesh	October-December
	Orissa	April-July
		November-January
	West Bengal	February-April
P. monodon	Goa	July-August
	Karnataka	October-April
	Tamil Nadu	March-May
		September-December
	Andhra Pradesh	September-April
	Orissa	April-May
		November-February
	West Bengal	April-May
		August-September
P. merguiensis	Gujarat	February-April
	Maharashtra	October-December
	Goa	February-May
	Karnataka	December-March
M. brevicornis	Gujarat	March–April
	West Bengal	July, Oct-December
M. affinis	Maharashtra	October-December
	Kerala	October-December
M. dobsoni	Goa	February-April/May
	Karnataka	October-April
M. monoceros	Maharashtra	October-December
	Goa	September-December
	Karnataka	October-April
	Kerala	October-December
	Tamil Nadu	March-September
P. sculptilis	West Bengal	May-June
	Andhra Pradesh	November-January
P. stylifera	Kerala	July-August

A REVIEW OF THE STUDIES ON LARVAL NUTRITION IN CULTIVABLE PENAEID AND PALAEMONID PRAWNS

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Introduction

The technological developments on large scale culture of prawns have been significant all over the world since the successful rearing of *Penaeus japonicus* by Hudinaga (Fujinaga) in 1942. In the initial phase of its development, efforts were mainly directed to develop appropriate technologies of breeding potential of cultivable species under controlled conditions and to delineate their larval development. Of late, however, there is great awareness of the importance of knowledge on the nutritional requirements of these species and the development of a feed technology for their successful culture operation. There is also a thinking that the triumph of future aquaculture of these animals largely depends on a sound understaning of these aspects as the diet in prawn culture is probably the most expensive input representing about 50-60% of the running cost of intensive culture operation from larvae to marketable size.

Information on prawn nutrition is relatively less as compared to those available on finfish nutrition. Prawns, as other crustaceans, derive nutrients directly from the media in which they live and from the ingested material. This makes the entire process of nutrition and its physiology, complex. The first review on the subject of feeding and nutrition, digestion and metabolism, and vitamins in crustaceans including certain cultivable species was made by Marshall and Orr (1960), Vonk (1960) and Fisher (1960) respectively. Subsequently, New (1976) offered an excellent review of the literature available on dietary studies with prawns and shrimps. This was followed by another comprehensive review by Kinne (1977). In an useful publication, Biddle (1977) covered various aspects of nutrition in fresh water prawns of cultivable interest. Apart from these, the books published by Imai (1977), Hanson and Goodwin (1977) and Stickney (1979) treat some aspects of nutrition of the candidate species dealt with by them. More recently New (1980) provided a bibliography of prawn and shrimp nutrition covering 494 literature published upto 1980, while Castell *et al*. (1981) presented the advances made in nutrition research on protein and amino acids, vitamins, lipids, minerals, carbohydrates and energy requirements and feed technology of crustaceans, molluscs and finfishes at the World Conference on Aquaculture and International Aquaculture Trade Show held in Venice in September, 1981.

Much of the work on prawn nutrition has been carried out on juvenile and adult forms. In the field of larval nutrition, most of the investigations carried out so far relate to identification and production of live feed and other natural material, and recently to artificial diets. Studies on quantitative aspects of food taken, total nutritional requirements of different larval stages, and those relating to their metabolism are few. In this paper an attempt is made to summarise the present knowledge of the food, feeding and nutrition of larvae of cultivable penaeid and palaemonid prawns as available from the published works.

Food and feeding of larvae

Qualitative as well as quantitative data on the nature and amount of food consumed by the larvae in the wild are scarce. This is mainly because of the constraints involved in studying the gut contents by the classical methods due to the delicate nature of the larvae, and the predominence of unrecognisable food in the gut. Structurally, the digestive tract of the larvae is simple and relatively short. However, it is observed that the Prawn larvae feed on a wide range of material of suitable particle size present in the water table available to them. This includes the phytoplankton, zooplankton and non-living particles. It is also observed that, in nature, they eat frequently and rapidly.

The type of food ingested and the feeding mechanisms are correlated with the characteristics of the different larval stages of penaeid and palaemonid prawns (New, 1979) and the functional morphology of their appendages (Muthu, 1980). In the penaeid prawns, the first larval stage, namely, the nauplius, does not feed and lives by utilising the internal yolk. After 2-3 days, the nauplius metamorphoses into protozoea stage and begins to feed on phytoplankton of approximately 3-10 μ size. After about 5 days, the protozoea transforms to mysis stage and feeds on particulate food of ten times the size of the food of protozoea. The mysis metamorphoses into postlarva after another 5 days and feeds mainly on particulate food of still large size and changes from an omnivorous to carnivorous feeding depending on the species. In palaemonid prawns, the eggs carried in the pleopods hatch out as zoea larvae and commence feeding on particulate food of the size of *Artemia* nauplii (0.4 mm) and even larger particles from the first or second day.

Studying the structure of the mouth parts and feeding appendages, Muthu (1980) classified the larvae of penaeid and caridean prawns into three broad categories, namely, the filter feeding type, the mixed feeding type and the carnivorous type. Accordingly, the protozoea and mysis of penaeids belong to filter feeding type with well developed maxillary filters; the postlarva of penaeids and zoea larvae of palaemonid prawns to carnivorous type with strong mandible, chelae of the first or more posterior pair of walking legs and raptorial setae, and the zoea larvae of the caridean prawns belonging to Hippolytidae, Processidae, Pandalidae, Crangonidae, Hoplophoridae and Atydae to mixed feeding type.

Dealing with the feeding habits of of crustaceans in general, Marshall and Orr (1960) grouped them into filter feeders, scavangers, predators and parasites. Among the filter feeders, they further observed, on the basis of the functional involvement of various mouth

parts and trunk limbs and the essential feeding mechanism, the trunk-limb filters, modified thoracic limb filters, maxillary filters, maxillular and mandibular filters and antennal and antennular filters.

Larval food in culture system

Live food organisms

Inadequacy of knowledge on the nature of food consumed by the larvae in the wild formed a constraint for a long time in successful rearing of prawns from egg through different larval stages. The development of pure culture of *Skeletonema costatum* by Hudinaga (1942) for feeding the protozoea of *Penaeus japonicus* paved way for the first time to rear the species through different larval stages. Besides *S. costatum*, Hudinaga offered *Artemia* nauplii for the late mysis and early post larval stages. For a long time *S. costatum* served as a classical feed for rearing of the early stages of penaeid prawns. In 1962, Fujinaga and Miyamura found that *Chaetoceros ridigus* is also suitable for the culture of early larvae of *P. japonicus*. Later studies showed that while *Skeletonema* cannot be cultured in high temperature, *Chaetoceros* spp. can withstand relatively high temperature and are found to be easily digestable by the larvae.

In the initial phase of the larval rearing history, it was thought that pure culture of suitable diatom was essential for larval feeding. However, in later attempts Fujinaga and Kittaka (1967) and Fujinaga (1969) used mixed cultures of diatoms in outdoor tanks with appreciable survival rate of larvae of *P. Japonicus*. Since then several diatoms of either pure culture or in combination were developed and used to feed the larvae by different workers (Table 1).

When the larvae are reared employing cultures of diatoms, generally a concentration of 5,000 – 20,000 cells/ml is used. It is reported that the larvae can be successfully reared through the different stages by feeding entirely on monoculture of the diatom, *Chaetoceros* at a higher concentration of 30,000–100,000 cells/ml (New, 1979). However, the success of diatom culture depends on several factors, and to achieve the maximum rate of survival and growth of larvae in the event of failure of diatom culture during the course of larval rearing, a series of studies were made on the use of combination of diatom with other foods. Mock (1972), Brown (1972) and Furukawa (1973) prescribed the use of preserved algae and yeast as supplemental feed when live algae are scarce. Bread yeast was offered with diatom to the larval stages in Philippines (Anon, 1976). Villegas *et al.* (1980) reported highest survival of *P. japonicus* larvae fed with a mixture of *Chaetoceros* and Baker's yeast.

The mysis and postlarva of penaeid prawn are normally fed with *Artemia* nauplii. Though it is a nutritious and convenient food, its availability and large-scale use in hatchery production of larvae are restricted due to high cost and variations in quality and food value of the different strains. In an attempt to finding out an economic alternative to *Artemia*, investigations were carried out on the use of rotifers, *Brachionus* spp. (Platon, 1978; Muthu, 1980), free living nematodes, such as *Panagrellus* (Samocha and Leweinsohn, 1977) and cladocerans like *Moina* spp. It was found that *Brachionus* and *Moina* offered

Table I. Important diatoms used in the rearing of Penaeid larvae

Diatom	Species of prawn	Reference
Skeletonema costatum	*Penaeus japonicus*	Hudinaga (1942)
Chlamydomonas sp. *Dunaliella* sp.	*P. duorarum*	Dobkin (1961)
S. costatum *Thalassiosira* sp. *Cyclotella nana* *Phaeodactyium tricornutum* *Dunaliella* sp. *Exuviella* sp. *Gymnodium splendens* *Isochrysis galbana*	*Penaeus* spp.	Cook and Murphy (1969)
Skeletonema costatum *Nitzschia closterium*	*P. japonicus* *P. monodon*	Liao and Huang (1973)
Coscinodiscus grandi *C. centralis*	*P. kerathurus*	FAO (1974)
Synachosystis sp. *Tetraselmis gracilis*	*Metapenaeus affinis* *M. dobsoni*	Thomas *et al.* (1976 a, b)
Cylindrothica sp. *Tetraselmis* sp.	*P. merguiensis* *P. japonicus* *P. aztecus* *P. semisulcatus* *M. ensis*	AQUACOP (1978)
Tetraselmis sp.	*P. monodon*	Platon (1978)
Chaetoceros gracilis	*P. merguiensis* *P. stylirostris* *P. vannamei*	Beard *et al.* (1977) Simon (1978)
	P. japonicus	Villegas and Kanazawa (1980)
Skeletonema sp. *Thalassiosira* sp. *Melosira* sp. *Nitzschia* sp. *Tetraselmis* sp.	*Penaeid* spp.	New (1979)
Chaetoceros, sp.	*P. japonicus*	Kurata and Shigueno (1979)
	P. indicus *P. monodon*	Muthu (1980)

in frozen form serve as effective food for the advanced larval stages.

In the culture of palaemonid prawns like *Macrobrachium rosenbergii* mixed algal culture developed from the wild plankton following the techniques of Fijimura (1966) was used for rearing the larvae in certain instances. These cultures were predominantly composed of *Chlorella* at concentrations ranging from 5×10^5 to 2×10^6 cells/ml (Sandifer *et al.* 1976). This rearing technique is mainly encountered in the static larval culture system using 'green water'. Successful rearing of larvae of *Macrobrachium* using single celled algae was reported by Fujimura (1966) and Minamizawa and Morizane (1970). In this connection, monoculture of selected species of algae such as *Chlamydomonas*, *Chlorella*, *Dunaliella*, *Isochrysis*, *Nannochloris*, *Phaeodactylum*, *Pseudoisochrysis*, *Skeletonema* and *Tetraselmis* was tested (Wickins, 1972; Maddox and Manzi, 1976; Manzi and Maddox, 1977). Manzi and Maddox (1977) obtained a production average of 59 post larvae/litre using *Phaeodactylum tricornatum* at densities of 340,000 cells/ml in the larval rearing tanks.

Although the larvae of *Macrobrachium* were successfully reared using the above algae, it was observed that phytoplankton was not an essential requirement for their culture. Sick and Beaty (1974) have shown that the algae have no nutritional value for the developing larvae of *Macrobrachium*. Nevertheless, there is evidence that the presence of phytoplankton in larval rearing tanks is beneficial as they are capable of converting the excretory products toxic to larvae to less harmful nitrates, thus improving the quality of water (New, 1979).

Macrobrachium larvae can be reared with a good survival rate on a diet of *Artemia* alone. Ling (1969) raised the larvae of *M. rosenbergii* on live zooplankton such as rotifers, cyclops, copepods, insect larvae, and chopped fish, shellfish and steamed chicken egg. Live feeds such as *Daphnia* and oyster larvae were also used. As better growth and survival of larvae were obtaind with a combination of food during the later half or two-thirds of larval development of this species, many feeds such as pulverised fish flesh, cooked egg custard, fish eggs and frozen adult *Artemia* are used to supplement the *Artemia* diet. Recently, Subramanyam (Giant fresh water prawn culture, CIFRI Technology, published by the Director, CIFRI, Barrackpore, year of publication not indicated) successfully reared *M. rosenbergii* through all the larval stages using different particle size of *Tubifex*. Besides the type of food used in larval rearing, Sick and Beaty (1974) reported that appropriate density and size of *Artemia* nauplii influence the growth and survival of the larvae to a great extent. They recorded that among several stocking densities, groups of larvae stocked at 20 to 40 animals/litre showed the best growth and survival rates and that only *Artemia* nauplii larger than 0.7 mm were ingested in adequate amounts to allow maximum rate of growth.

Mass Culture of live food organisms for larval feeding

a. Culture of microalgae

In the hatchery production of prawn seed, a reliable and abundant supply of

live food of appropriate size is of paramount importance. Although concerted efforts are put in to replace the live food organisms by artificial feeds, the former still play a major role serving as principal food during the part or whole of the larval development. Realising this, intensive attempts on large scale culture of microalgoe and zooplankton are carried out by several investigators (Ukeles, 1976; Shaw Watson, 1979; Kinne, 1977 and Kahan, 1982). As a resualt of these studies, considerable progress has been made on large scale algal production technology. Recently, de pauw and Pruder (1981) reviewed the various modes of use and production of microalgae in aquaculture, the biological and technical problems encountered, economic implications and the major research task to improving the system. Similarly the advances made and the constraints faced in large scale production and supply of *Artemia*, and of several non - *Artemia*, live food organisms were reviewed by Sorgeloos (1981) and Nellen (1981) respectively.

Generally, two methods are followed for mass culture of microalgae. In the first method the selected algae are grown in the culture media with or without the supply of nutrients or addition of fertilizers in outdoor tanks of various sizes and shapes using an external light source. Often the algae are cultured along with the consumer species. The second method entails the culture of algae under controlled conditions providing optimal growth conditions such as nutrients, pH, light and agitation. The former is an extensive approach, less expensive, but unreliable for culture of selected or preferred species. The algal culture raised by this system often gets contaminated with other species and production rate is also found to be relatively less than in intensive algal culture. However, the out-door algal culture is found to be suitable for short period, semi-intensive culture and as a valuable supplement to intensive culture system.

At the Narakkal Prawn culture Laboratory (NPCL) of the Central Marine Fisheries Research Institute (CMFRI), mixed culture of phytoplankton predominated by *Chaetoceros* is raised in filtered sea water with fertilisation in white one ton fibre glass tanks utilising solar energy (Muthu, 1980). Successful outdoor culture of valuable species in nurtient rich water from oceanic upwelling was reported by Yoneshigue-Braga and Rodriguez (1975) and Moreira dasilva (1976). Sea water from deep wells was also used for mass culture of algae in Hawaii, while Dunstan and Mensel (1971) and Mann and Ryther (1977) reported the use of sea water enriched with sewage effluent solar irradiated tanks for the dense culture of microalgae. Recently, Radhakrishnan *et al*. (1980) studied the effect of various cheaply available organic substances in the mass culture of selected brackishwater microorganisms under yard conditions. To the filtered brackishwater enriched with a dose of yeast, extracts of cowdung, ground nut oil cake, vegetable leaves, powdered blue green and green algae were added and it was found that the leaf extract alone and in combination with the other organic substances gave the maximum yield of microorganisms. In another study, Joseph *et al*. (1980) studied the utili-

sation of bottom slush from polluted estuarine areas for plankton production.

The intensive culture of microalgae is generally restricted to the culture of selected monospecies and their further upscaling for feeding on large scale. This system required energy intensive steps and careful monitoring of various parameters promoting the balanced growth conditions.

Important steps involved in algal culture are 1) separation of the desired species and maintenance of its stock culture in agar slants or as liquid culture, 2) inoculotion to culture vessels containing appropriate culture media, (3) cultivation with supply of nutrients and other congenial conditions of temperature, salinity, carbondioxide concentration, light, pH and agitation and (4) separation, concentration and harvesting of the cultured species. Ukeles (1977) described the different types of culture vessels, media used and culture techniques developed in indoor mass production of algae. The light source is either natural light or artificial source using flourescent lamps fitted above or around the culture vessels. Recently, transparent polythene containers of 30 to 480 litre capacities are used (Persoone and Sorgeloos 1975; Baynes *et al.* 1979). Devices have been developed for automatic harvesting and replenishment of the culture medium (Trotta, 1981) reducing the labour and construction cost. Helm *et al.* (1979) discussed the design, construction, operation and cost structure of algal culture in 200 l vessel, while Laing (1979) described the methods and media for the batch culture of *Chaetoceros calcitrans* in 2 l, 20 l and 200 l stages.

b. Culture of Artemia

Great strides have been made in recent years on the mass production of *Artemia* which serve as an ideal prepacked larval food (Kinne, 1977; Mohsen Al-Khares *et al.* 1980; Sorgeloos, 1981). It has a world-wide distribution occuring in super saline waters. It is either harvested from the natural source or cultured under controlled conditions in sea water by feeding with various material such as yeast, rice bran, dried algae, beef extract or organic detritus. In the NPCL of CMFRI continuous culture of 3 strains of *Artemia* are maintained in 6' diameter plastic pools feeding with the juice taken out of ground nut oil cake. The research results obtained on hatching quality and on the techniques of harvesting the cysts have appreciably enhanced the production of *Artemia* and its use. Recently, it has been shown that *Artemia* can be successfully transplanted and insulated to a new locality leading to the local production to meet the increasing demand.

c. Culture of Zooplankters

Besides *Artemia*, the most important zooplankton mass cultured for feeding prawn larvae, are rotifers, cladocerans and copepods. Among rotifers, the most widely cultivated species is the euryhaline rotifer, *Brachionus plicatilis* Muller. The technique of mass culture of the species is now well established (Kinne, 1977). In the culture of the species, they are fed with different algal diets such as *Chlorella, Dunaliella, Exuviella, Gymnodium, Monochrysis, Nannochrysis,* bacteria and marine yeasts. Recently, Trotta (1980) described a simple and inexpensive system for continuous culture of *B. plicatilis* fed on live *Chlorella,*

producing daily about 1 million individuals. The harvest concentration was 300/ml. The culture vessel was plastic bags. At the NPCL of CMFRI, continuous mass culture of *B. plicatilis* is carried out in 24' diameter outdoor tanks containing brackishwater. The medium is fertilised with groundnut oil cake which induces dense *Chlorella* blooms. Within 6–7 days high concentration of rotifers (0.5 to 0.6 million/l) is developed. The rotifers are harvested by specially designed silk nets and washed well. They are then frozen into small blocks containing 10–15 million rotifers and stored for use in larval rearing.

Several freshwater species of zooplankters such as *Chirocephalus,* daphnids and *cladocerans* were tried as larval food. Among these, *Moina* received considerable attention in our country. At the NPCL of CMFRI, the species obtained from the local freshwater ponds are mass cultured in out door plastic pools containing freshwater which is fertilised with ground nut oil cake juice. It is found that they develop very fast attaining a concentration of 30,000 – 40,000/l in 6–7 days. They are harvested in the same manner as for the rotifers and frozen into small blocks containing 0.5–0.75 million animals for furture use. Recently, a breakthrough was reported in obtaining dry cysts of *Moina* with appreciable shelf-life.

Copepods form an important food in the rearing of the advanced larval stages of prawns. Various aspects of copepod culture are reviewed by Kinne (1977), Paffenhofer and Harris (1979), Nellen *et al.* (1981) and Kahan (1982). Although, several workers have achieved considerable success in the culture of copepods, calanoids, harpacticoid copepods such as *Tigriopus* and *Tisbe* and recently, the brackishwater cyclopoids (James and Thompson, 1980) on experimental basis, they have been used only to a limited extent in mariculture hatchery systems. Major constraint encountered was to maintain an adequate density of the culture involving light, temparature, salinity, oxygen, pH and other organic waste products in the culture medium. Recently, Kahan *et al.* (1982) developed a simple method for cultivation of Harpacticoid copepod in a floating basket in the larval rearing tanks and discussed the advantages of the method in producing various size and stages of copepods for larval feeding.

Chemical composition of live food organisms

It is well known that the live food organisms serve as ideal food for the developing larvae. Chemical composition of several microalgae and other live food organisms (Table 2) provide the relative nutritive value. It is observed that the diatom such as *S. costatum, Chaetoceros* sp. and *Phaeodactylum* and *Artemia, B. plicatilis, Moina* sp. and *Tubifex* that are currently used in larval rearing possess appreciable levels of macro-nutrients. Although prominent synthesis of protein occurs in diatoms, increased synthesis of fats and carbohydrates at the expense of protein as well as variations in protein/carbohydrate ratio is reported in prolonged batch cultures of certain algae.

Non-living and non-conventional food

In recent years several non-living and non-conventional feed were found

useful in rearing of the larvae of prawns. Hirata *et al.* (1975) successfully used soy cake powdered to a particle size of less than 100μ for rearing protozoea stages of *Penaeus japonicus*. However, in subsequent experiments, they found that a combination of soy cake powder and diatom produced the best results. Powdered fat free rice bran (Ishida, 1967), activated sludge (Imamura and Sugita, 1972), marine yeast (Furukawa, 1973), washings of filamentous algae and Sargassum juice (Anon, 1976), fermented extract of vegetable refuse from kitchen and egg yolk (Anon, 1977) estuarine detritus (Qasim and Easterson, 1974) and decomposed mangrove leaves (Sumitra Vijayaraghavan and Ramadhas, 1980) are some of the non-conventional feeds used in larval and postlarval culture with varying results. More recently Hameed Ali (1980) and Hameed Ali *et al.* (1982) reported successful rearing of larvae of *P. monodon*, *P. indicus*, *P. merguiensis*, *P. semiculcatus*, *Penaeus* sp., *M. monoceros*, *M. affinis*, *M. dobsoni*, *M. brevicornis* and *Parapenaeopsis stylifera* from protozoea through postlarval stage feeding exclusively on a diet of crustacean such as *Acetes indicus*, *Palaemon tenuipes* and *Mesopodopsis* fresh tissue of suitable particle size maintained in a suspension state. Alikunhi *et al.* (1980, 1982) had also achieved success in the large scale rearing of larvae of penaeid prawn fed with tissue suspension prepared with juveniles of *M. dobsoni* and stomatopod crustaceans.

In the rearing of *M. rosenbergii*, Subramanyam (Vide, Giant fresh water prawn culture, CIFRI Technology) offered plant products such as soy beans, maize, sorghum, coconut oil cake and cotton seed cake as supplementary feeds alongwith rotifers, brine shrimp nauplii and tubificid worms.

Artificial diet

With the increasing commercialisation of aquaculture of prawns, the demand for suitable feed and their steady supply is ever increasing. Large scale production of microalgae and other live food organisms is found widely fluctuating and often contaminated by unwanted species. Besides this, a great amount of manual labour, large quantities of culture medium, and vessels and equipments are involved in their production, adding considerably to the running cost of the culture operation. In an attempt to overcome these constraints, several attempts have been made to rear prawns on artificial diets (Subrahmanyam and Oppenheimer, 1969; Kanazawa *et al.* 1970; Forster and Gabbott 1971; Cowey and Forster, 1971; Shigueno, 1975; Sick *et al.* 1972; Kitabayashi *et al.* 1971, a, b, c; Aquacop 1978, Goswami and Goswami 1982; Raman *et al.* 1982; Mohamed Sultan *et al.* 1982; Ahamed Ali 1982). However, most of the diets developed were used to growing juveniles in the nursery and grow-out systems. Shigueno (1975) compounded diet with squid meal, squid extract, petroleum yeast, activated gluten, alpha-starch and vitamin and mineral mix in particulate size to rear larvae of *P. japonicus* and reported some success. Later, Villegas and Kanazawa (1980) prepared an artificial diet (Diet B) composed of glucose (5.5% in dry weight), sucrose (10%), starch (4%) glucosamine (0.8%), lipid and vitamin-free casein (50%), Na-succinate (0.3%), Pollack residual oil (8.1%),

Table 2. Chemical composition of some important live food organisms offered to prawn larvae

Organism	Percentage dry weight				Reference
	Protein	Carbo hydrate	Fat	Ash	
Tetraselmis maculata	52	15.0	2.9	—	Parsons *et al.* (1961)
Dunaliella salina	57	31.6	6.4	—	
Chaetoceros sp.	35	6.6	6.9	—	
Skeletonema costatum	37	20.8	4.7	—	
Phaeodactylum tricornatum	33	24.0	6.6	—	
Exuviella sp.	31	37.0	15.0	—	
Chaetoceros sp. (unialgal culture growing exponentially)	48.6	9.2	9.5	—	Lewin and Guillard (1963)
S. costatum (unialgal culture growing exponentially)	60.6	34.71	7.7	—	
S. costatum (unialgal culture, grown 2-4 weeks)	43.52	34.55	21.93	—	
P. tricornatum (unialgal culture growing emponentially)	35.7	25.9	7.1	--	
P. tricornatum (fusiform cells from 16-d culture)	46.5	2.2	38.6	—	
P. tricornatum (oval cells from 16-d culture)	37.7	21.1	26.6	—	
Diatom *(Chaetoceros)* *	29.0	8 0	63.0	—	From Marshall and Orr (1960)
Diatom (Mixed) *	24.5	14.2	61.3	—	
Mixed zooplankton *	46.0	6.0	23.0	25	
Artemia nauplii	55.60	—	15.20	15.25	Gallagher and Brown (1975)
Brachionus plicatilis	59.07	8.44	24.05	8.44	Charles John Bhaskar (1982)
Moina sp.	56.69	13.47	23.73	6.11	
Tubifex	65.0	15.0	14 0	6 0	Bardach *et al.* (1972)

* Grams per 100 gram Organic matter

cholesterol (0.5%), mineral mix (8.6%) vitamin mix (2.7%)' cellulose powder (9.3%) and water 130-135 ml. Agar was used as a binder. The powdered diet, passed through a sieve of mesh size 10-50 μm, was offered to the larvae from protozoea stage at a feeding rate of 0 16 mg/larva/day. The result of this dietary experiment showed that the larvae metamorphosed into mysis stage in 8 days with a survival rate of 53.2%.

In 1974 Sick and Beaty formulated 6 types of diets with varying composition of fish meal, soybean meal, shrimp meal, with or without albumin and *Artemia*, vitamin and mineral mix, alginate, linseed oil, Menhaden oil and cellulose in three forms, namely, freeze-dried, gel and dry flake, and experimented with *M. rosenbergii* larvae. The results of the experiment indicated that the larvae fed with the diet in freeze dried form with *Artemia* meat grew through all the stages, and the heighest rate of ingestion was observed by the 7-8 stage larvae with freeze-dried diet with *Artemia*.

At the NPCL of CMFRI, the larvae of *P. indicus* are being successfully reared from protozoea to postlarvae on a micro-particulate compounded feed prepared from mantis shrimp, prawn waste, ground nut cake, fish meal and tapioca with a survival rate of over 35%. Besides this, several feeds compounded with indigenously available raw material having different levels of protein, carbohydrate, lipid and other micro nutrients and different particulate size are experimented with the larvae and postlarvae of *P. indicus* with encouraging results (Ahamed Ali, MS).

Following the report on the use of the technique of micro-encapsulation for supplying artificial diet to filter feeding larvae by Jones *et al.* (1974) and Jones *et al.* (1976), Moller *et al.* (1979) experimented with the mysis larvae of *P. merguiensis* on a microencapsulated diet and successfully reared them to postlarva II. Subsequently, Jones *et al.* (1979) formulated different micro-encapsulated diets (particle size of 20 μm to 100 μm) with chicken egg, short-necked clam *(Tapes phillippinarum)*, soy cake and the purified diet (Diet B) earlier developed by Kanazawa *et al.* (1977) to rear *P. japonicus* from protozoea to postlarva. They found that optimum particle size of diet for protozoea I larvae was 10 μm and as the larva advanced to Mysis II and III stages it selected larger size particles of about 28 μm. The postlarva was seen to feed only on food particles larger than 28 μm size. They further observed that micro-encapsulated diet of *Tapes* and egg produced 50% survival rate and it would be possible to achieve still higher survival rate if the right particulate size diet is given in appropriate quantity and with proper management of water quality. Further studies on the large scale production and economic use of microencapsulated diets for larval rearing and to find out the nutritional requirement of the different larval stages are progressing.

Feeding Rate and Frequency

It is well known that, to achieve significant growth and survival, the food supplied should be properly ingested and assimilated by the prawn. In this context, information on the amount of food that is actually consumed by the

animal and frequency of feeding is essential. Such data are also essential for designing and evaluating the diets. In nature, it is observed that prawns eat frequently and rapidly. As their digestive tract is short, there is only a little time for absorption of food. Further, in caridean prawns the gastric mill is not present in the anterior chamber of proventriculous as in the penaeid prawns, and hence the dry food is observed to congest the proventriculous and hamper proper enzymatic mixing with the food (New, 1979).

The feeding rates in prawns have been reported to range from 3 to 20% of the total biomass of the animal per day (Subrahmanyam and Oppenheimer, 1969; Kanazawa *et al*. 1970 and Brown, 1972) and the ingestion rates are inversely related to the animal size.

In the rearing of penaeid prawns. *Artemia* nauplii are usually supplied at densities varying from 0.3-3 nauplii/ml, while the postlarva is found to consume 50-90 *Artemia* nauplii per day. In the culture of *Macrobrachium* larvae with *Artemia* as food, a density of 5 to 10 nauplii/ml is generally provided. Sick and Beaty (1974) studying the relative rate of ingestion in *M. rosenbergii* with 6 formula diets, found that stage 7 and 8 larvae consumed higher amount of the diet containg *Artemia* meat. Similarly, the diets having a balanced starch albumin ratio and 15% egg albumin were taken at a relatively higher rates in freeze dried form than any other diets prepared in flake or gel forms. Villegas *et al*. (1980) recorded the highest survival (76 8%) of *P. monodon* larvae fed on a mixture of *Chaetoceros* and baker's yeast at feeding levels of $10 - 50 \times 10^3$ cells/ml and 1g / ton / day respectively. When the larvae were fed on *Chaetoceros* sp. alone, the optimum feeding level was found at a density of $10 - 50 \times 10^3$ cells/ml.

Venkataramaiah *et. al* (1975b) observed that pellets of 1–2 mm diameter were taken by the postlarvae of 9 mm size and above. If the pellets offered were of larger size, the postlarvae (9-15 mm long) were seen sitting on them and nibbling. Sometimes a single pellet was carried by more than one postlarva. They also found that the feeding ratio in *P. aztecus* during the process of growth from postlarvae (9.5 mm) to sub-adults (100 mm) bear roughly inverse relationship to the body weight, the feeding level being 100% of body weight in the early postlarvae, decreasing gradually to 5% of the body weight in the sub-adults Food consumption in *P. aztecus* was found to depend on water temperature and to a lesser extent on salinity concentration of medium. At a temperature of 31°C, *P. aztecus* was very active feeding at more than 11% rate while at a low temperature (21°C) it was sluggish and failed to consume the food offered at 8% feeding rate. However, increase in food consumption with temperature failed to yield the proportionate growth. The optimal feeding levels for the species was found at 6.2, 8.1 and 11% at 21, 26, and 31°C respectively (Venkataramiah *et al*. 1975 b)

Experimenting with microencapsulated diet Jones *et al*. (1979) recorded that *P. japonicus* larvae died within 10 days at Mysis 1 stage when fed at a concentration of 100 capsules/ml, but a

feeding concentration of 500–1000 capsules/ml, the larvae metamorphosed successfully from protozoea to postlarva. At the 1000 capsules/ml level, the larval mortality was found to be high, particularly in the protozoea stage. The feeding level of 500 capsule/ml was found to give better results. With the microparticulate diet, Kanazawa *et al.* (1977) found better growth rates at a feeding rate of 0.16 mg/of diet per larva per day. At a higher concentration of 1.6 mg/larva/day of feeding rate, mass mortality occured due to pollution of the rearing medium by the diet. Hirata *et al.* (1962) reported a survival rate of 85.9% in the rearing of P. japonicus larvae at the end of 6th day feeding soy cake particles at a rate of 0.16 mg/larva/day.

Several factors such as age, behaviour and physiological conditions of the species, light, substratum, biomass composition and physical and chemical characteristics of food influence the rate of ingestion of food. Feeding 3–4 times per day is found to be better than feeding once in a day. Sick *et al.* (1973) found that the ingestion rate decreased significantly in *P. setiferus* fed on a pelleted diet after 6 hours of exposure to the same food, probably due to changes in the physical and chemical characteristic of the food

The chemosensory properties of diets are found to attract shrimps for feeding. Substances such as betaine (trimethylamonium hydroxide), morin (a fragrant aromatic compound), egg-white protein and non-essential amino acids such as glutamic acid, glycine, and taurine are found to stimulate the prawns into feeding activity. It is reported that one private company in the USA has patented a food using a mixture of mono–sodium glutamate with sodium or potassium aspartate, which induces hunting and feeding reactions in prawns.

Nutritional Requirement

In recent years several studies have been carried out to understand the nutritional requirements of prawns and shrimps with diets of different protein, carbohydrate, lipid, mineral and vitamin composition. While the results of these studies have considerably contributed to the knowledge of the nutritional demands of these animals, there is wide difference in the observation of the various workers on the requirements of the optimum dietary level of both macro and micronutrients which provide the optimum growth and the highest survival rate in a given species of prawn. Further, most of these studies relate to the nutritional requirements of juveniles and sub-adults, the information on dietary requirements of larvae being utterly scarce.

It is observed that the nutritional requirements of larvae may be different from those of juveniles and adults consequent upon the behavioural and dietary changes occuring during metamorphosis through different stages. The pattern of life and mode of feeding also changes as the larvae grow to advanced stages. An attempt is made here to summarise the existing knowledge on the dietary requirements of prawns as it would facilitate investigations on the nutritional requirement of larvae which forms an area of immediate concern in the development of suitable feed in the hatchery production of seed.

Determination of optimum dietary levels of protein has been the subject of several studies (Kanazawa *et al.*, 1970; Lee, 1970; Kitabayashi *et al.* 1971 a, b, c and Deshimaru and Shigueno, 1972; Andrews *et al.* 1972; Balazs *et al.* 1973; Forster and Beard, 1973; Colvin, 1976; Deshimaru and Kuroki, 1975; Venkataramiah et al., 1975a; New, 1976 and Ahmed Ali, 1982a). Although the protein level as investigated in these studies ranges from 15 to 80% in the diet, it is generally opined that a protein level of 27-35% is the optimum requirement for the juvenile penaeids. It is also observed that with better understanding of the aminoacid profile of the prawn, source of protein and synergetic effects of the dietary component, still lower levels of protein may be adequate to obtain satisfactory growth. Working with the larvae of *Palaemon serratus* Van wormhoudt (1973) found that protease activity in the larvae is related to dietary changes occuring during metamorphosis. Recently, Charles John Bhasker (1982) conducted dietary experiments with purified (casein, starch, lipid (fish oil and ground nut oil), vitamins, minerals and cellulose) and semi-purified (casein, tapioca powder, ground nut oil, vitamins and minerals) diets with the post-larvae of *P. indicus* and found that the protein requirement in the diet decreased with increased in size of the post-larva and the optimum protein requirement was between 30 and 40% when adequate levels of carbohydrate (35-40%) and lipid (10%) were used.

Requirements of specific amino acids were studied by Cowey and Forster (1971), Kittabayashi *et al.* (1971 a, c, d,) Deshimaru and Shigueno (1972) and Torres (1973) in penaeid prawns and Miyajima *et al.* (1975) and Watanabe (1975) in *Macrobrachium ohione* and *M. rosenbergii* respectively. About 10 amino acids such as arginine, histidine, leucine, isoleucine, lysine, metheonine, phenylalanine, threonine, tryptophan and valine are found to be essential for penaeid prawns. In *M. rosenbergii*, however it has been shown that the species could synthesize most of the essential amino acids in adequate level (Watanabe, 1975; Stahl and Ahearn, 1978). The amino acid profile is found to differ in different parts of body of the prawns (Shewbart *et al;* 1972) and from species to species.

The nutritional importance of carbohydrates in prawns was studied by Tyagi and Prakash (1967), Cowey and Forster (1971), Forster and Gabbott (1971), Kitabayashi *et al.* (1971,d), Andrews *et al.* (1972), Sick and Andrews (1973) and Ahamed Ali (1982). Herbivorous shrimps showed strong carbohydrase activity. Generally, glucose is found to be poorly assimilated than corn or wheat starch and oyster glycogen (Forster and Gabbott, 1971). However, a suitable dietary carbohydrate is found to be necessary to spare or preclude the use of carbon chain from amino acids for chitin synthesis (Cowey and Forster, 1971). Van wormhoudt (1973) reported that in the larvae of *Palaemon serratus* amylase activity varied in different larval stages reaching the high level in the 2nd stage. Ahamed Ali (1982) studying the effect of carbohydrate in purified diets observed that the growth of *P. indicus* juveniles enhanced with the increase in carbohydrate dietary level upto about 40%. Highest growth was recorded at

5% lipid at each carbohydrate level. This observation indicates that the performance of the diet could be improved by increasing the dietary carbohydrate level due to its protein sparing action. Studies have also been carried out on carbohydrate metabolism (Dall, 1964) and on the absorption rate of specific monosaccharides (Sick ank Andrews, 1973).

Athough lipids form an important source of energy, it is found that prawns do not require high levels of dietary fat and lipase activity is limited (Andrews and Sick, 1972). It is reported that addition of lipid to the diet at different levels (7.5 to 20%) adversely affects the growth and survival of the prawn (Andrews *et al.* 1972; Forster and Beard, 1973). However, it has an attractant quality. Tissue lipid levels are found to vary from season to season and during the moulting cycle. The Important fatty acids in prawns are palmitic acid and W_3 polyunsaturated fatty acids. It is observed that W_3 fatty acids are retained in the tissue, while W_6 fatty acids are mobilised for energy. However, the low levels of the former and the high levels of the latter are found to have inhibitory effect. Recently, it has been shown that linoleic, linolenic and W_3 - long chain polyunsaturated acids are essential in the diet of the prawn (Kanazawa *et al.* 1979) and a requirement between 1 and 2% for linolenic acid has been indicated (Shewbart *et al.* 1973). Jones et al., (1979) examined the fatty acid biosynthesis in the larval stages of *P. japonicus* and found that the highest larval growth rates were achieved on diets containing *Tapes phillippinarum* lipid. This study also revealed that 16 : 1W 7, 18 : 0 and 18 : 1W 9 fatty acids may be synthesised from palmitic acid and the larvae possess the ability to elongate 18 : 3W3 to 20 : 5W3 and 22 : 2W6 and 18 : 2W6 to 20 : 4W6. However, as their conversion rate is found to be slow, it is reported that eicosapetaenoic acid (20 : 5W3) and decosahexaenoic acid (22 : 6W3) are essential in the diet.

Prawns, like other crustaceans, cannot convert acetate into sterols which are hence required in the diet (Teshima and Kanazawa, 1971). A cholesterol level of 0.5% in the diet is found to be better than 0.05 or 1% while a higher level of 5% seem to depress the growth. A basic diet containing 0.5% cholesterol supplemented with inokosterone, cyasterone or ecdysterone extracted from plants is found to increase the moulting frequency. It is reported that *P. japonicus* converts desmonsterol into cholesterol and C_{28} - and C_{29} - sterols for growth.

Information on nutritional requirements of mineral and vitamins of prawns is limited. Kitabayashi *et al.* (1971 a) recorded greater growth rates when phosphorus and calcium were added to the diet. However a calcium/phosphorus ratio of above 2.4 : 1 was found to depress the growth. It was reported that Mg and Fe are nonessential, but 2% P, 1% K and 0.2% of a trace element premix was useful (New, 1979)

Fisher (1960) reviewed the requirement of vitamins in crustaceans in general. Most of the B-group vitamins, vitamin C and E are found to be essential. Although vitamin A seem to be not essential, it is found in several species of penaeids. Kitabayashi *et al.* (1971 b) found accelerated growth of *P. japonicus* with vitamin C in the diet. Most of

the prawn diets include vitamin A or β-carotene and vitamin K. There is little information on the dietary level of vitamins, although 0 5-1% of vitamin C and 0.4% of inositol were found to be optimal requirement by some workers (New, 1979). It is cautioned that improper use of vitamins without understanding their role in the diet may produce toxic or antagonistic result.

General Remarks

The successful application of aquaculture technology for increased production of prawns depends on the development of a viable culture system with a feasible technical, economic, marketing and social approach. Sustained demand, large scale production and marketing of the farmed prawns in its turn greatly depends on the acceptance of the produce by the consumer who is primarily interested in the quality of the product, its appearance, odour, flavour and texture. In all these, the quality and quantity of the food consumed by the prawn, its assimilation and absorption play an important role.

In the mass rearing of prawn larvae that transforms into different stages within a short period, with structural modification of feeding apparatus and changing their food regime, the selection of a suitable food of appropriate size is important. The selected food should be physically available close to the larvae, easily tackled, digestable, metabolizable and meet the nutritional requirement of the larvae; it should not pollute the medium in which the larvae are reared. In recent years considerable progress has been made in the technology of large scale culture of valuable live food organisms, particularly the microalgae which form the major food source in the controlled rearing of prawns. However, in the uncontrolled extensive method of mass production of microalgae in outdoor tanks using the natural source of light, the major problem encountered is the fluctuation in production The algal production is influenced by factors such as nutrients, characteristics of the medium and its environmental parameters and availability of light. Blooms of unwanted and often toxic species which develop in the culture tanks also pose problems, as they lead to mass mortality of larvae. Although this system is less expensive, it is labour intensive.

The controlled production of monospecific microalgae for direct feeding of larvae has met with some success in experimental and small scale operations. But constraints are encountered when the defined algal culture is upscaled to feeding the larvae in the hatchery due to premature collapsing of the cultured species and contamination with other species. In this context, further studies on the growth requirements of microalgae in order to increase their life span and to find out reasons for premature collapsing when upscaled are essential. Information on the nutritional value of the microalgae used in the larval rearing is also an essential prerequisite to select the most suitable species from among the several used at present Data on the relative efficiencies of the different systems of algal production along with the cost would help in developing suitable design to meet the requirement of huge quantity of food in hatchery production of prawn seed. The

development of a technology for proper preservation of microalgae for use in adverse or emergency situation would go a long way in the successful hatchery production of prawn seed.

In the field of development of formula, compounded diet suitable for intensive culture of prawns, there has been appreciable progress in recent years. Several diets formulated by using locally available ingredients, commercial meals and chemical ingredients of different protein, carbohydrate, lipid, mineral and vitamin mix represent the attempt made and contribute to the understanding of their use. By and large the studies carried out with the formula diet describe the levels of macro and micro nutrients in the diet, the relative growth and survival rates obtained in the experiments, physical characteristics of the diet and to some extent, the nutrirional requirement of the species. However, comparison of the relative merits of the diets is made difficult due to the varieties of dietary ingredients used and contradication in the results obtained and the observations made. Thus there is inconsistency as to the optimum dietary requirement of protein, carbohydrate and lipids. Studies on nutritional requirements of micronutrients have received relatively less attention.

It is only since the past decade the larval nutrition attracted the attention and ways and means of solving the physical problems of larval diet were suggested. Besides the requirement of suitable particle size of the food the artificial larval diet should be palatable, its nutrient must not leach out, it should not pollute the water and it should be easily available to the delicate larvae. As a result of the investigations carried out so far, a few diets for the larvae have been developed, the latest being the microencapsulated feeds of 15–100 μm size. However, these diets are yet to be used in large scale production of seed and commercialised.

Data on nutritional requirements of larvae are limited to a few recent investigations (Sick and Beaty 1974; Sick, 1976; Jones *et al*. 1979; Villegas and Kanazawa, 1980). There is little information on the nutritional requirements of cultivable species of penaeid and palaemonid prawns of India, although the recent technical advances made on the development of microencapsulated diets have greatly helped to study these aspects. A major research task is needed on several aspects of larval nutrition, the important areas being total nutritional requirements of different larval stages of cultivable species, development of inexpensive but balanced diet of suitable particale size with locally available ingredients, determination of caloric requirements of larvae, nutritional diseases of larvae and the development of viable feed technology to produce the enormous quantity of larval feed required in large scale production of seed of cultivable penaeid and palaemonid prawns.

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PENAEID BROODSTOCK DEVELOPMENT AND MANAGEMENT

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Introduction

In the context of the global interest in the aquaculture of penaeid prawns, production of large quantities of quality prawn seed in hatcheries has become imperative. For efficient planning of hatchery operations, ripe spawners of the desired species should be readily available at the proper time. In Japan where there is an organised industry for the capture and marketing of live-prawns, obtaining spawners for the hatcheries is not a problem. But in all other countries where there is no such trade, getting spawners from the wild by trawling is expensive and uncertain. This has generated keen interest in the induced maturation of penaeid prawns under controlled conditions and in the development and management of prawn broodstock as anintegral part of the hatchery.

The research work conducted in many parts of the world from 1971 to 1979 on problems connected with induced breeding of marine prawns in captivity were reviewed by Muthu and Laxminarayana (1982). In the present discussion the recent advances in this rapidly growing field of research are included and the results of these investigations carried out during the past decade are evaluated with special reference to management of penaeid broodstock for producing spawners under controlled conditions.

Reproduction of Penaeid Prawns

At the outset, some aspects of penaeid reproduction relevant to broodstock developmet and management are summarised here. In nature penaeid prawns breed only in the sea. They are sexually dimorphic, the male being generally smaller than the female. The males may become mature even in brackishwater ponds but the females never attain full ovarian development in such ponds. The males produce non-motile sperms which are packed inside spermatophores. At the time of mating the male transfers the spematophores with the help of its petasma to the thelycum of the female. In penaeids with a closed thelycum (e. g. *Penaeus indicus, P. monodon* etc.) mating takes place between a newly moulted "soft" females with immature ovaries and a mature male in the intermoult phase; the sepermatophores are tucked safely inside the seminal receptacles, dorsal to the thelycum where they are retained until the prawn moults again; there is a long time lag between mating and spawning. In penaeids with open thelycum (e. g. *P. styliferus, P. vannamei, P. stylirostris* etc.) mating takes place between a "hard" intermoult female with ripe ovaries and a hard mature male in the intermoult phase; the spermatophores are attached superficially on the surface

of the thelycum and can easily be dislodged; spawning takes place soon after mating. In both types of penaeids, at the time of spawning the male is not present; the female simultaneously releases the eggs from the oviduct and the sperms from the spermatophores and fertilization takes place in the seawater.

The hormonal mechanism of reproduction in penaeid prawns is not fully understood but is likely to be similar to that of the other decapod crustaceans discussed by Adiyodi and Adiyodi (1970, 1974). Egg production in prawns, as in other crustacea, is a cyclic phenomenon under the hormonal control of the neurosecretory centres. Among these centres, the X-organ sinus gland complex in the eyestalk seems to produce a gonad inhibiting hormone (GIH) which inhibits vitellogenesis, while the centres in the brain and thoracic ganglia appear to produce gonad stimulating hormones (GSH) which promote vitellogenesis (Kulkarni and Nagabhushnam. 1980, Nagabhushanam and Kulkarni, 1982). During the quiescent phase of the ovary the X-organ seems to produce a high titre of GIH which restrains vitellogenesis either directly or through its action on the neurosecretory centres which produce the GSH. In nature, when the physiological and environmental factors are conducive to reproduction, the titre of the GIH secreted by the X-organ complex is probably reduced, thereby allowing vitellogenesis to take place under the influence of GSH. On the basis of this hypothesis the technique of unilateral eyestalk ablation has been evolved for inducing the penaeid prawns to mature in captivity. By removal of one eyestalk, the titre of the GIH is arbitrarily reduced and this leads to ovarian development.

Induced maturation of penaeid prawns

By providing optimal environmental conditions and suitable feeds in land-based maturation facilities with flow through seawater systems, many species of penaeid prawns such as *P. californiensis* (Moore *et al.*, 1974), *P. japonicus* (Aquacop, 1975; Laubier – Bonichon, 1978); Laubier-Bonichon and Laubier 1979; Caubere *et al.*, 1979; *P. merguiensis* (Aquacop, 1975; Beard *et al.*, 1977), *P. vennamei* (Aquacop, 1977 b), *P. stylirostris* (Aquacop, 1979; Brown *et al.*, 1980), *P. setiferus* (Brown *et al.*, 1979), *P. indicus* (Primavera *et al.*, 1982) and *Metapenaeus ensis* (Aquacop, 1975) have been successfully made to mature and spawn naturally without eyestalk ablation.

But species which do not mature under these conditions have been induced to mature and spawn in captivity by the well-known eyestalk ablation technique. Some of the important species which have responded to this treatment are *P. merguiensis* (Alikunhi *et al.*, 1975; Nurijama and Yang, 1977), *P. monodon* (Aquacop, 1977 a, 1979, 1982; Santiago, 1977; Chen, 1977; Primavera, 1978 a, b, 1982; Primavera and Borlangan, 1977; Primavera *et al.*, 1978; Halder, 1978; Beard and Wickins, 1980; Tiensongrasmi, 1980; Muthu and Laxminarayana, 1981), *P. duorarum* (Caillouet, 1973), *P. aztecus* (Aquacop, 1975), *P. kerathuras* (Lumare, 1979); *P. plebejus* (Kelemec and Smith, 1980,) *P. orientalis* (Arnstein and Beard, 1975), *P. indicus* (Muthu and Laxminarayana,

1979, 1981). Even species that matured and spawned without eyestalk ablation responded to unilateral eyestalk ablation with more rapid gonadial maturation and repeated spawnings (Aquacop, 1979; Brown *et al*., 1979; Lawrence *et al*,. 1980; Primavera *et al*. 1982).

Bilateral vs. unilateral eyestalk ablation

Eversince Panouse (1943) discovered that eyestalk removal led to premature ovarian development, eyestalk ablation has been a research tool for exploring the hormonal mechanisms in crustaceans (Adiyodi and Adiyodi 1970). Idyll (1971) and Caillouet (1973) first applied this technique to induce maturation of penaeid prawns in captivity. But bilateral eyestalk ablation, although leading to rapid ovarian growth, did not result in spawning; the ova got reabsorbed without being released from the ovary (Caillouet, 1973; Duronslet *et al*., 1975; Aquacop, 1975; Wear and Santiago, 1976). Very soon it was realised that unilateral eyestalk ablation successfully lead to ovarian maturation and subsequent spawning (Arnstein and Beard, 1975; Wear and Santiago, 1976). The lack of success with bilateral eyestalk ablation may be due to the fact that the crustacean eyestalk produces, apart from the GIH, a number of neurosecretory hormones which (1) regulate lipid metabolism and protein synthesis in the hepatopancreas, (2) induce hyperglycaemia in the blood to combat stress, (3) regulate calcium metabolism during cuticle formation, (4) affect the water balance during ecdysis, (5) inhibit production of moulting hormone by the *Y* – organ and (6) influence the movement of pigments in the chromatophores (Hignam and Hill, 1978). When so many vital physiological functions are jeopardised by bilateral eyestalk removal, it is bound to have repercussions of the gonads also. In unilateral eyestalk ablation the presence of one eyestalk seems to ensure normal functioning of all the metabolic processes.

Methods of eyestalk removal

Cutting the eyestalk near the base with a pair of scissors (Arnstein and Beard, 1975; Lumare, 1979), scissor cutting followed by cauterisation with pencil-type soldering iron (Caillouet, 1973), electrocauterisation (Muthu and Laxminarayana, 1979, 1981), pinching of eyestalk (Aquacop, 1977), squeezing the eyeball contents out (Rodriguez, 1979), incision of eyeball, squeezing out the contents and crushing the eyestalk (Primavera, 1978a and b) and incision of eyeball followed by enucleation of contents (Kelemec and Smith, 1980) are some of the methods used for getting rid of the eyestalk ganglia containing the neurosecretory organs which secrete, store and release the GIH. Electrocautery seals the cut instantly, avoiding blood loss and ensures cent percent survival (Muthu and Laxminarayana, 1981). In the other methods, some loss of blood is inevitable but the procedures are simple.

Source of broodstock

Broodstock of prawns have been constituted from immature adults caught from the sea (Moore *et al*., 1974: Brown *et al*., 1979: Rodriguez, 1979), from large sized prawns cultured in brackishwater ponds (Primavera, 1978a; Muthu and Laxminarayana, 1981) or from

postlarvae grown to adult size in controlled systems (Laubier – Bonichon, 1979; Aquacop, 1975, 1977b, 1979; Beard *et al.*, 1977). The source of the prawns is immaterial as long as the specimens have attained the size and age at which the species normally matures, The most convenient source of broodstock is, of course, the grow-out ponds where some of the prawns can be allowed to grow for a longer period to attain maturation size.

Age of broodstock prawns

The Age at which the prawns are capable of maturation varies with the species.

Species	Age at first maturation in months	Reference
P. merguiensis	4–5	Aquacop (1975)
Metapenaeus ensis	8	Aquacop (1975)
P. japonicus	12	Aquacop (1975)
P. aztecus	12	Aquacop (1975)
P. monodon	7–12	Aquacop (1979)
P. vannamei	12–15	Aquacop (1979)
P. stylirostris (Panama strain)	7–9	Aquacop (1979)
P. stylirostris (Mexican strain)	5–7	Aquacop (1979)
P. merguiensis	6–7	Beard *et al.* (1977)
P. monodon	12–15	Primavera *et al.* (1978) Santiago (1977)
P. monodon	5	Primavera (1978 a)
P. indicus	4	Primavera, *et al.* (1982)
P. indicus	4–6	Personal observations.

Primavera (1982) has shown that in *P. monodon* the quality of the eggs (in terms of viability of the larvae) produced by the 5 month old pond reared females are inferior to the eggs produced by 1–2 year old wild females. She feels that the older females from the sea are more responsive to induced maturation than the younger females from the ponds, although the latter may be equal in size to the former due to the higher growth rate in the pond environment. She recommended that the pond reared *P. monodon* females should be allowed to remain in the grow-out ponds for about one year before they are utilised for induced spawning by eyestalk ablation.

Sex-ratio

In the broodstock pools usually males and females are kept in the ratio of 1:1. But Aquacop (1975) observed that for *P. merguiensis* 25% males were sufficient for regular fertilization. Caubere *et al.*, (1979) also successfully used only 30% males in their experiments with *P. japonicus*. Primavera (1982) reported that a male : female ratio of 1:2 produced the highest percentage of spawnings, highest average fecundity and the greatest number of eggs in *P. monodon* and recommended the ratio as economical because it maximises the number of females per tank. The present author found that if spermatophores are extracted from the terminal ampoules of male *P. indicus* another set of spermatophores become ready for extrusion within two hours thereby indicating that the same male is capable of fertilising more than one female in a day.

Latency period

Literature on eyestalk ablation reveals that maturation after eyestalk removal can be very rapid. Some females are able to develop full ovaries and spawn in 3–5 days but if moulting occurs soon after eyestalk removal the maturation period is extended to 2–3 weeks (Aquacop, 1979). Generally, the white prawns such as *P. merguiensis*, *P. indicus*, *P. vannamei* and *P. stylirostris* mature more rapidly (3–4 days) than *P. monodon* and *P. aztecus* (3 weeks). Lumare (1979) found that ablated *P. kerathurus* kept at a constant temperature of 25° C took 43–69 days to spawn in November – December, 30 days in March and only 10 days in May – June, i. e. they appear to mature faster as their natural breeding season is approached.

Rematuration

Unilaterally ablated females repeatedly mature and spawn viable eggs (Primavera, 1978b, 1982; Primavera and Borlangan, 1977; Aquacop, 1979, 1982; Lumare, 1979; Brown *et al.*, 1980; Lawrence *et al.*, 1980; Beard and Wickins, 1980). In one intermoult period of 20 – 30 days, *P. monodon* has been observed by Beard and Wickins (1980) to spawn upto 6 times, at intervals of 3–5 days without appreciable decline in number of the eggs spawned; but the hatching rate declined in later spawnings. This shows that one impregnation was sufficient to fertilize several batches of eggs spawned within the intermoult period. The decline in hatching rate of the later batches of eggs perhaps indicates reduction in number and viability of the sperms towards the end of the intermoult period. In two successive intermoult periods a single *P. monodon* spawned eleven times in 2 months, 6 times after the first mating and 5 times after the second mating (Beard and Wickins, 1980).

Even unablated females kept in flow through systems have been observed to remature and spawn repeatedly (Moore *et al.*, 1974; Aquacop, 1975; Laubier-Bonichon and Laubier, 1979 Caubere *et al.*, 1979, Beard *et al.*, 1977 and Brown *et al.*, 1979).

Egg quality

The quality of the eggs spawned by eye ablated *P. monodon* has been studied by Aquacop (1977 a) who described 4 types of eggs. Type 1 eggs

are unfertilized, characterised by several unequal big "cells"; Type 2 eggs have fragmented internal membrane and do not develop into nauplius. Type 3 eggs have asymmetrical embryo that dies in the egg or hatches out as weak nauplius and Type 4 eggs are the normal eggs with symmetrical embryo. They found that if the mature females are isolated and kept in a separate 2 m^3 tank and fed with *Troca* flesh for 2 days before spawning, the quality of the eggs produced by such females was better than that of the eggs produced by females which were directly transferred from the broodstock pools into the spawning tanks (Aquacop, 1979). Primavera and Posadas (1981) recognised 5 egg types in *P. monodon,* A1, A2, B, C and D. The A1 eggs are the normal eggs giving rise to healthy nauplii, A2 eggs are slow in development and hatch out into abnormal nauplii with deformities, B eggs are unfertilised with irregular cytoplasmic formations: C eggs are unfertilised with no segmentation at all and D eggs are also unfertilised with the cytoplasm invaded by bacteria. The hatching rate was directly proportional to the number of A1 eggs in the spawning. Primavera and Posadas (1981) recommended that if the hatching rate fell below 30% it is better to discard that batch of eggs, as such spawnings are likely to give rise to weak larvae. They also found that unablated wild spawners from the sea produced the largest number of eggs with the highest proportion of A1 eggs (49.3%), followed by ablated wild stock (38.9%), while ablated pond stock produced the least number of eggs with the lowest percentage of A1 eggs (23.5%). Efforts to improve egg quality in ablated pond stock by better nutrition and broodstock management are urgently needed.

Physical facilities used for broodstock maintenance

Maintaining marine animals in captivity is difficult, but making them breed in captivity is still more difficult. They should be provided with an environment which simulates their natural habitat. Three types of systems have been used to maintain penaeid brood stock viz. (i) marine pens (ii) flow-through systems and (iii) recirculating systems.

Marine pens

Bamboo pens 250 m^2 in area, constructed in sheltered tidal bays and coves where the depth of water is 4–6 m, have been used in the Philippines by the SEAFDEC (Wear and Santiago, 1976; Santiago, 1977; Rodriguez, 1979) to keep the broodstock of *P. monodon.* The pens are constructed of bamboo slats tied to a framework of bamboo poles and lines on the inside with nylon netting of 1.5 cm mesh. A large net made of similar nylon webbing is hung inside the enclosure touching the mud bottom. The prawns are held in this net which can be hauled up periodically to catch the prawns and examine them for signs of gonadial development. Free exchange of tidal water through the nylon netting brings in fresh oxygenated water and removes the metabolites from the pen. In fact, the prawns are living in their own natural environment which is only circumscribed by the pen.

Flowthrough systems

On the west coast of Mexico, Moore *et al.*, (1974) have used 23 x 3 x 0.6 m raceways under inflated polyethelene bubble canopy to hold the broodstock of *P. californiensis*. Seawater from a well on the seashore was pumped continuously through the system, the flowthrough rate being 700% per day.

In France, Laubier-Bonichon and Laubier (1979) and Caubere *et al.*, (1979) employed circular tanks 2.9 m and 5 m in diameter with flowthrough rates of 450 litres and 200 litres per hour respectively. Since they were working with *P. japonicus*, a burrowing species, their tanks had a substratum of sand over a false bottom through which water was recirculated by air lifts to prevent anaerobic conditions from developing in the sand.

In Tahiti, Aquacop (1975, 1977 a & b, 1979) held their prawn broodstock *(P. monodon, P. merguiensis, P. japonicus, P. vannamei, P. stylirostris, P. semisulcatus, P. aztecus* and *M. ensis)* in 4 m diameter circular fibreglass tanks. The tanks had a substratum of coral sand. Oceanic seawater pumped directly from the lagoon outside was supplied to the tanks through perforated concentric PVC pipes embedded in a layer of gravel below the coral sand. The water welling up through the substratum dislodged the detritus from the bottom and kept them in suspension. These suspended particles left the tank along with the out-flowing water which drained through two concentric drain pipes in the centre of the tank. The water exchange rate was 2-3 times a day. At the SEAFDEC, Philippines the Aquacop model was adopted (Tolosa, 1978); instead of fibreglass the tanks had ferrocement walls.

Primavera *et al.*, (1978) also tried using a 7.25 x 7.25 x 1 m concrete tank having limited water renewal for *P.monodon* broodstock with less success.

In the U. S. A., Brown *et al.*, (1979) and Brown *et al.*, (1980) used 3 m circular fibreglass tanks with central drain pipe and no substratum on the tank bottom for *P. setiferus* and *P. stylirostris* respectively. The tanks had continuous flowthrough of seawater with a turnover rate of 1.8 to 4 times a day. Lawrence *et al.*, (1980) utilised a 4.9 m circular tank with the bottom, which had no substrate, sloping towards the middle, for holding the broodstock of *P. setiferus;* 80–90% of the water was exchanged every 2–3 days.

Recirculation systems

In U. K. Beard *et al.*, (1977) have successfully bred *P. merguiensis* in 2.9 x 1.65 x 0.3 m concrete tanks fitted with sub-gravel filters through which water was recirculated by air-lift pumps. 50% of the water was renewed every week. Beard and Wickins (1980) used similar tanks for *P. monodon* but the water was recirculated by pumping through a biological filter which was kept outside the holding tanks.

Lumare (1979) in Italy made use of 2 x 2 x 1 m cement tanks fitted with sub-sand filter through which seawater was recirculated at 6 times the water volume per day, for keeping a broodstock of *P. kerathurus;* 1/3 of the water was replaced every day.

Kelemec and Smith (1980) in Australia employed a 2.4 x 1.5 x 0.6 m tank fitted with sub-gravel filter and air-lift recirculation for making *P. plebejus* mature in captivity, the recirculation rate was 6 times the water volume every hour and water replacement varied from 2.5% to 5% per day.

At the Narakkal Prawn Culture Laboratory of the CMFRI, 3.6 m circular plastic lined pools fitted with sub-gravel filters, through which seawater is recirculated by air-lifts, are used for the broodstock (Muthu and Laxminarayana, 1980).

Merits and demerits of the different systems

Among the three types of systems mentioned above, the marine pens offer the most natural environment for the broodstock but they also have a number of drawbacks; (i) Calm protected bays suitable for construction of the pens may not be available in the neighbourhood of the hatchery. (ii) The bamboo enclosures get worn out easily and have to be repaired or replaced frequently. (iii) For examining the prawns the whole net has to be hauled up subjecting the prawns to considerable stress. (iv) There is no control over the environmental parameters.

The other two systems which are land based and relatively more permanent could form part of the hatchery and make use of the seawater pumping and aeration facilities, already available at the hatchery, for the broodstock tanks. They are also amenable to greater environmental control and facilitate closer observation of the maturing prawns. If good quality seawater is freely available, the flowthrough systems are to be preferred; the faster the rate of water flow the better it is for the broodstock, as the metabolites will not be allowed to accumulate in the system. But if the maturation facility is situated far away from the sea, the recirculation systems come in very handy. In this case it is imperative that the seawater in the system be recirculated through a biological filter, which may be inside the tank or outside it, to oxidise the toxic ammonia secreted by the animals into relatively harmless nitrates through the activity of the bacteria that grow on the filter material (Spotte, 1970).

In the land-based maturation facilities a substratum of sand is provided for burrowing species such as *P. japonicus*, *P. aztecus*, *P. semisulcatus* *P. duorarum* and *P. vannamei*. But for non burrowing species such as *P. indicus*, *P. merguiensis*, *P. setiferus*, *P. stylirostris*, *P. monodon* etc., the tank need not have a sandy substratum. It is advantageous to have a plain bottom from the point of view of tank cleanliness.

In recirculating systems it is advantageous to keep the biological filter outside the holding tanks so that the prawns that dash around the pool at the time of capture do not get injured by abrasion against the filter components. Further a built-in sub-gravel filter or sub-sand filter competes for available oxygen in the tank water and will lead to rapid depletion of oxygen when aeration is stopped due to current failure or other mechanical reasons.

Factors that affect maturation and Spawning of Penaeid Broodstock

A number of factors have been observed to affect the process of matu-

ration and spawning of the captive broodstock. They are classified under three major heads viz. physical factors, water quality and biological factors and discussed in this section.

Physical factors

Some information on the effect of light, temperature and pressure on the reproduction of penaeid prawns in captivity are available.

Light

It is well known that light is an important factor influencing the gonadial maturation in a number of animals. Some work has been done on the effect of photoperiod on the maturation of the sub-tropical species such as *P. japonicus* (Laubier-Bonichon and Laubier, 1979; Caubere *et al.*, 1979) and *P. kerathurus* (Lumare, 1979). Although these prawns matured when the photoperiod was gradually increased it cannot be concluded that increase in photoperiod was solely responsible for making them mature because in the experiments on *P. japonicus* the temperature was also simultaneously increased in a gradual manner. Further, Lumare (1979) found that *P. kerathurus* matured faster in November - December when the light period was 9 hrs per day than when it was 12 hrs per day. Therefore, when the evidence is not conclusive even in species living in sub-tropical regions where the seasonal change in photoperiod is relatively marked, it is unlikely that the photoperiod has any effect on tropical penaeids accustomed to a more or less equal day / night regime throughout the year.

However, the intensity of light seems to affect the maturation process. In almost all the investigations referred to in the foregoing sections, the maturation pools were either kept inside a room with weak artificial lighting or the tank had covers that reduced the light intensity to 10-40% of natural day light. In nature the prawns breed on the bottom of the sea where the intensity is bound to be very low. Strong light in the maturation pools may be a source of stress to the prawns, especially the non-burrowing species. In this connection it may be interesting to mention that Brown *et al.*, (1979) found that *P. setiferus* when kept in a circular tank painted white on the inside sustained injuries by dashing against the wall, but quietened down when the walls were painted black. Emmerson (1980) working with eye ablated *P. indicus* found that by painting the broodstock pools black on the inside, the maturation process could be accelerated and the number of eggs produced by the females increased. More work is needed on the relationship between light intensity and maturation in penaeid prawns. The optimum light intensity is likely to vary for different species depending on their burrowing habits, swimming behaviour etc.

The colour of the light may have some influence on the maturation process as the blue component of light is predominant at the bottom of the sea where the prawns live and spawn. The experiments of Caillouet (1973) and Alava (1979) on the effect of colour of light on maturation of *P. duorarum* and *P. monodon* respectively were, however, inconclusive.

Temperature

Temperature of the water in the maturation pools is bound to influence

the rate of all physiological processes including the maturation of the gonads. Laubier-Bonichon and Laubier, (1979) and Caubere *et al.*, (1979) found that *P. japonicus* matured and spawned when the temperature was gradually increased from 15° C to 24° C over a period of 3 months. Aquacop (1979) found that *P. monodon* matured and spawned throughout the year if the temperature was above 24° C. The tropical species of penaeids have been found to mature rapidly when the temperature of the water in the maturation facilities was between 28 – 30° C.

Pressure

Since prawns are demersal in habit it was thought that pressure might influence the reproductive process. Caubere *et al.*, (1979) found that mature females, subjected to a pressure of 2.5 kg per m^2 (the pressure at 20 m depth in the sea) for 12 hrs, spawned. But mature females also spawned even without pressure treatment. Pressure does not seem to have any effect on the maturation process either, since Beard *et al.*, (1977) have obtained full maturation of gonads in *P. merguiensis* kept in a tank with only 0.3 m depth of seawater.

Water quality

The quality of water in the broodstock pools has a profound influence on the maturation of the prawns. It stands to reason that the water quality should be as close to that of natural seawater the native medium in which penaeid prawns attain full maturity and spawn.

Salinity

The fact that even those penaeid species which spend their juvenile life in estuaries and brackishwaters migrate to the sea for spawning, suggests that salinity is an important factor that affects the maturation process. This gains credence from the observations of Morris and Bennett (1952), Johnson and Fielding (1956), Liao (1973), Chen (1976), Muthu and Sampson Manickam (1978), Licatowich *et al.*, (1978) and Rodriguez (1981) who have reported female penaeids with mature gonads from coastal ponds and lagoons where the salinity was equal to that of seawater. In all the maturation facilities the salinity of the water is maintained between 27 – 34 ppt. However, comparative experiments have not been conducted to study the effect of different salinities on the maturation of the penaeids in captivity.

pH and inorganic carbon

In recirculation systems pH declines rapidly due to the physiological activity of the prawns stocked in the pool and may become a limiting factor when it reaches 7.3 (Wickins, 1976a). The process of bacterial oxidation of ammonia to nitrates by the biological filter also leads to reduction in pH and loss of inorganic carbon from the water, both of which affect the calcification of the cuticle and the normal moulting process in prawns (Wickins, 1976b). So a completely closed system of recirculation is not desirable; at least a part of the water has to be replaced by fresh seawater every day or required amounts of sodium carbonate or bicarbonate added regularly to maintain the pH and inorganic carbon content

of the water in the pools. Maturation of the broodstock has been most rapid when oceanic water, having a steady pH of 8.2 was continuously flowing through the system (Aquacop 1975, 1977b, 1979).

Ammonia and nitrate

The toxicity of ammonia and nitrate to penaeid prawns has been studied by Wickins (1976). He found that the maximum acceptable level of ammonia (the concentration at which growth is reduced only by 1-2% compared to the controls) is 0.1 mg NH_3 - N / litre for penaeid juveniles. Wickins (1976a) also observed that at a nitrite level of 6.5 mg NO_2 - N / litre the growth of juvenile *P. indicus* was reduced to 50% of that of the controls. *P. japonicus* was found to be more sensitive to nitrite, 5% mortality occurring at 0.1 mg NO_2 - N / litre (Mevel and Chamroux, 1981). While these values may be appropriate for normal growth of prawns in culture systems, the broodstock prawns may be more sensitive requiring much lower concentrations of ammonia and nitrite for gonadial maturation. At the NPCL the total ammonia concentration in the broodstock pools fitted with biological filters is as low as 0.02 - 0.07 mg ammonia N / litre and the nitrite level only 0.0003 to 0.0012 mg NO_2 - N/litre. It is obvious that as long as the biological filters are functioning properly, ammonia and nitrite will not pose problems for the broodstock prawns.

Biological factors

Biological factors such as food, physiological stress, diseases and injuries and mating success also affect the reproduction of the broodstock prawns.

Food

Broodstock prawns have generally been fed *ad libitum* on fresh or frozen mussel, clam, oyster or squid meat. A high protein diet rich in essential amino-acids and long chain polyunsaturated fatty acids appear to be necessary for maturation of ovaries. Deshimaru and Shigueno (1972) found that the aminoacid profile of clam and squid meat is very similar to that of prawn flesh and hence these two organisms are excellent sources of protein for feeding cultured prawns. Brown *et al.*, (1980) and Lawrence *et al.*, (1980) have used polychaete worms to feed the broodstock of *P. stylirostris* and *P. setiferus* respectively with encouraging results. The efficacy of the polychaete diet is attributed to the fact that these worms are very rich in long chain polyunsaturated fatty acids (C 20:4; C 20:5; C 22:6) which are found to be essential components of ovarian lipids of penaeid prawns (Middleditch *et al.*, 1979; 1980a). The prawns are not capable of biosynthesizing these long-chain unsaturated fatty acids (Kanazawa and Teshima, 1977; Kanazawa *et al.*, 1979a 1979b, 1979c) and hence these fatty acids should be supplied in the diet of the broodstock prawns in adequate amounts for proper ovarian growth. On the basis of the fact that in several animals the C 20 fatty acids are precursors of prostaglandians which have been found to play a vital role in the reproduction of higher animals. Middleditch *et al.*, (1979) suggested that the reproduction

of prawns is also mediated by prostaglandins derived from these fatty acids. The clams and mussels fed to the broodstock prawns usually have mature gonads which may be supplying the essential fatty acids and carotenoids needed for the ovarian development of prawns. The fact Middleditch *et al* , (1980b) have found that bivalves are rich in C 20:4, C 20:5 and C 22:6 fatty acids.

Stress

Stress due to handling, overcrowding and poor water quality is a major factor inhibiting the maturation of gonads in captivity. *P. monodon* is particularly sensitive in this respect (Aquacop, 1979); regression of developing ovaries is frequently observed in this species. To avoid handling stress, Aquacop (1979) and Primavera (1982) used an underwater torch at night for determining the stage of maturation of the gonads. The light tied to a long pole is held close to the prawn in such a way that the beam of light strikes perpendicular to the upper part of the body making the dark green mature ovary prominently visible.

Aquacop (1979) found that in broodstock tanks stocked with a biomass of over 300 gm/m², the prawns did not attain maturity. The usual stocking density in land-based maturation tanks is 3-7 animals per m², the lower density being preferred for larger species such as *P. monodon* (Muthu and Laxminarayana, 1982)

Prawns stop feeding when the water quality deteriorates due to inefficient functioning of the biological filter, disruption in aeration or recirculation of water, accumulation of unused food etc. and this leads to resorption of the developing ovaries in the broodstock prawns (personal observation).

Mating success

Although males easily attain sexual maturity in captivity even under brackishwater conditions, instances of inability to mate with females in the maturation facilities have been observed by a number of workers (Arnstein and Beard, 1975; Brown *et al.*, 1979; Beard and Wickins, 1980; Kelemec and Smith, 1980; Aquacop, 1979 and personal observat ions), the reason for this is not quite clear. Primavera (1979) felt that the mating behaviour of *P. monodon* calls for a large pool with sufficient area for swimming about freely if impregnation is to take place normally. But Aquacop (1979); Brown *et al.*, (1679), Beard and Wickins (1980) and Kelemec and Smith (1980) have reported lack of impregnation in broodstock kept in large tanks also. Aquacop (1979) found that the proportion of impregnated females was less in penaeids with open thelycum (eg. *P. vannamei* and *P. stylirostris*) because the spermatophores could be easily dislodged. However, they found that by keeping the males and females in separate tanks and introducing only the ripe females into the male tank a few hours before spawning, the impregnation of the female could be assured. Similarly, Bread and Wickins (1980) observed that even in *P. monodon* which has a closed thelycum impregnation is assured if the female is kept separafe from the males and introduced into the male tank when it is about to moult. Separation of males and females seems to increase the attraction between them.

Diseases and injuries

Brown *et al.*, (1979) have reported that *P. setiferus* males in the broodstock pools were susceptible to a *Vibrio* infection of the terminal ampoule which damaged the structure of the spermatophore, making it impossible for the spermatophores to stick to the open thelycum of the females. At the NPCL the present author has frequently observed black patches on the thelycum of impregnated female *P. indicus* kept in the broodstock pools; such females invariably produced non-viable eggs. The present author has also observed abnormal sperms without spikes or completely disintegrated sperms inside spermatophores extracted from the terminal ampoule of male *P. indicus* kept in the broodstock pools, specially during the hot summer months. Broodstock kept for a longer time in the pools also get cuticular lesions on the abdomen and such females are not able to produce viable eggs, although they may mature and spawn.

Conclusion

Development and managemet of penaeid broodstock as part of a hatchery system has benefitted by a multidisciplinary approach. Such diverse disciplines like endocrinology, reproductive biology, nutritional physiology, waste water treatment, patho-biology, hydrology, engineering etc. have contributed to progress in this field of research. It is now possible to make almost all the commercially important species of penaeid prawns to mature and spawn in captivity, either through manipulation of environmental parameters or through eyestalk ablation. However, more scientific knowledge is urgently needed on (1) the normonal mechanisms involved in reproduction of the prawns (2) the role of dietary components in promoting ovarian growth (3) the spawning triggers (4) the factors that affect fertilization (5) the sexual behaviour of males (6) sperm viability and (7) diseases that affect the broodstock. A greater understanding of the ways in which the environmental and biological factors affect the maturation and spawning processes in prawns is necessary for improving the quality and quantity of the eggs produced by the captive broodstock. New engineering designs to improve the efficiency and reduce the construction costs of the physical facilities such broodstock tanks, biological filters, flow-through and recirculating systems etc. are also necessary.

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HATCHERY PRODUCTION OF PRAWN SEED

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Introduction

The successful spawning of the Japanese prawn *P. japonicus* and the rearing of its larvae through various stages under controlled conditions achieved by Hudinaga (1935, 1942) have opened up series of developments all over the world leading to commercial cultivation of marine prawns. By adopting and adapting Hudinaga's methods several species of penaeid prawns have been successfully spawned and their larval forms reared to a stockable size under controlled conditions by various workers in different countries (Cook and Murphy, 1969; Huang *et al.*, 1969; Liao and Huang, 1973; Aquacop, 1977; Ewald, 1965; Muthu *et al.* 1977, 1978; Raje and Ranade, 1972; Devarajan *et al.* 1978; Silas and Muthu, 1977; Mohamed *et al.* 1978; Thomas *et al.* 1975, 76a, 76b, 77). The methods followed by these workers have undergone several changes resulting in development of more efficient techniques for production of seed prawns in large quantities for commercial prawn culture.

It is now widely accepted that increased production of prawns can be brought about through employing systematic culture of prawns in coastal marine impoundments. A number of marine penaeid prawns have been identified as suitable candidate species for culture in various parts of the world as a result of the extensive investigations undertaken by several workers. A detailed list of the species in which artificial propagation has been achieved is given in Appendix 1. Among the various culturable species of prawns available in India, the Indian White prawn, *Penaeus indicus* and the tiger prawn, *Penaeus monodon* are the most popular and it is on these two species much of the work in this country is in progress at present.

The culture systems developed during the years following Hudinaga's success with rearing of *P. japonicus* can be broadly classified as two types. 1) The mass culture system exemplified by the Japanese method of simultaneously spawning a number of spawners in large cement concrete tanks where the seawater is fertilized to develop food organisms and 2) A closed – cycle hatchery system developed by the scientists of the Galveston laboratory, USA, in which the spawning is conducted in small fibreglass tanks and the larvae are fed from external source of separate live feed cultures. This second system is considered as more sophisticated and has been adapted and used by several workers and agencies.

Spawners

Hatchery operations start with procurement of spawners. Availability of spawner prawns in ready-to-spawn condition of ovarian maturity is a factor dependant on season and infrastructural facilities for transport of the same to the hatchery. Although Initial work on prawn breeding has been carried out with the help of spawners obtained from the wild, the use of spawners induced to maturation from captive stock of the farms has also gained practice in recent years. The well known method of eyestalk ablation to induce maturation in crustaceans is now being practiced as a routine procedure at the Narakkal Prawn Culture Laboratory (NPCL) of the Central Marine Fisheries Research Institute for developing spawners of *Penaeus indicus* for their regular use. Since brood stock development and maintenance is the subject matter of another section of the symposium it is not necessary to go into the details here.

Hatchery systems

The well known Japanese system of hatchery for penaeid prawns consist of large cement concrete tanks of 60 to 200 tonne capacity, which are provided with the aeration systems and rotating agitators (Hudinaga and Kittaka, 1967; Hudinaga, 1969; Shigueno, 1975; Yang, 1975). The tanks are cleaned, dried and filled with fresh seawater to a height of 0.4 meter before spawners (@1 spawner per m^3 of tank capacity) are introduced in cage nets. After the spawning, the spawners are removed along with the cage net leaving the eggs and hatched-out larvae in the tank. Rearing of the resultant larvae takes place in the same tank into which more water is pumped in and regularly fertilised with nutrients to promote blooms of naturally occurring diatoms. Vigorous aeration is provided through airstones from a compressed air grid and the water is agitated by slowly rotating vanes attached to an electric motor. On the second day the diatoms bloom (attain 5,000 to 20,000 cells/ml concentration), providing ideal food for the protozoea. The zooplankton organisms also develop on the following days forming food for the mysis stage larvae. The feed environment created by these procedures is very closely similar to conditions obtaining in the sea and this is considered to be an advantage. From the first day of mysis to the 4th day of post-larvae fresh seawater is pumped into the tank every day until the water level of the tank is increased to 2m from its original level of 0.4m. Supplementary feed in the form of *Artemia* nauplii for mysis and crushed and washed clam meat or ground soy bean waste are also given for postlarval stages.

By this procedure about 1 million prawn fry (P_{35}) are obtained from each 10 m x 10 m x 2 m tank. Modifications in the feeding pattern have been introduced into this practice by several workers. In Taiwan Liao and Huang (1973) used oyster larvae (produced by artificial fertilisation) whenever phytoplankton did not develop well. Bread yeast was used along with mixed diatoms to feed the protozoea and mysis in Philippines (Anon, 1976b). Separately cultured rotifer *Brachionus* was also used to feed mysis and early postlarval stages.

Facilities constructed elsewhere at high cost using this technology has not been so successful. Apart from

the cost, the chief disadvantage of the method is the uncertainity or lack of control over the production of desired species of phytoplankton at appropriate time and frequent development of blooms of undesirable species of plankton organisms such as dinoflagellates leading to mass mortality of larval stock. In order to exercise control over these factors several workers started developing and using separate live feed cultures to feed the larvae. In Japan and Philippines although large concrete tanks are still used for spawning and rearing of the larvae, large scale live feed cultures are also maintained and used as a regular practice.

Besides, it has become more and more clear that high initial strength of nauplii resulted in poor survival rate (Fuginaga, 1969; Shigueno, 1975; Liao and Huang, 1973; Anon, 1976a and b). The Philippine workers (Anon, 1976) suggest a very low concentration of larvae-not exceeding 6000 larvae/ton of seawater-and the use of only 6 spawners (of *P. monodon)* even in a 200 tonne concrete tank. The main reason for high mortality in crowded tanks appears to be the accumulation of metabolites produced by the larvae themselves and this problem is surmounted by the Japanese workers by increasing the tank size and by use of greater volumes of seawater to dilute the metabolites released by the larvae. The method is, however considered wasteful as a greater portion of the food added to the system will be unutilised and since it involves extra cost in pumping of seawater.

The closed-cycle system of hatchery for breeding of prawns and rearing of larvae developed by the scientists of the Galveston laboratory in USA (Cook and Murphy, 1976, 1969; Cook, 1969; Mock and Murphy, 1977; Mock and Neal, 1974; Salser and Mock; 1974) is based on an integrated system of several independant processes requiring higher technical inputs. The entire process is carried out in smaller containers and the chief operation of larval rearing is made independant of the live feed cultures thereby exercising greater control over management and quality of water.

Cook (1969) originally used a smaller fibreglass tank of 946 litre capacity for spawning and a small inverted 19 litre polyurethane carbuoy for rearing the larvae upto postlarval stage. He along with Murphy (1969) scaled up the operation using 1890 litre cylindrical polyethylene containers fitted with a small seawater recirculating system for both spawning and larval rearing. He used pure cultures of desirable species of diatoms and unicellular algae to feed the protozoeal stages; the concentration of phytoplankton in the system being maintained at a density of 10,000 to 15,000 cells/ml with the help of an automatic dispensing system. Freshly hatched brine shrimp nauplii were given at the rate of 3-5/ml of water for feeding the larvae from mysis stage onwards. This system has been further improved by Salser and Mock (1974) by introducing cylindro-conical fibreglass containers of $2m^3$ capacity for rearing larvae. The shape of this container facilitates easy cleaning and efficient dispersal of food. The aerating stones kept at the bottom of the cone ensured vigorous vertical move-

ment of water which kept the food particles in constant motion. Separate facilities for phytoplankton culture and large scale hatching and collection of brine shrimp nauplii are essential components of this system.

Cook (1969) has been able to produce 2000 postlarvae in 15 litres of seawater in the Carbuoy i. e. 133 postlarvae/litre as against the yield of 5-10 post larvae/litre by the Japanese method. Although this system is brought out as a small scale operation unit, it enables exercise of strict controls over the essential parameters responsible for successful rearing of the larvae.

This method has been further modified and used in Tahiti (Aquacop, 1975; 1977), in Philippines (Platon, 1978) and in the United Kingdom (Beard *et al.*, 1977) to produce postlarvae of penaeid prawns. The changes brought about in the process of this development include increase in initial stocking density of 50-100 nauplii/l, use of higher concentration of phytoplankton bloom (30,000 to 100,000 cells/ml) for feeding protozoea, feeding rotifer (5-10/ml) to the mysis stage and *Artemia* nauplii (5/ml) for postlarvae $P_1 - P_5$.

In India, attempts for breeding of prawns under controlled conditions can be said to have started with the commencement of the *Ad hoc* scheme on 'Prawn Culture and Propagation' sanctioned by the ICAR in 1975. The scientists of Narakkal Prawn Culture Laboratory (NPCL) established under the scheme by the Central Marine Fisheries Research Institute, after having completed the preliminary work of larval rearing of the cultivable Indian species of marine prawns, (see appendix) took up the work on mass production of prawn seeds. Silas and Muthu (1977) reared larvae of *Metapenaeus dobsoni* and *M. affinis* in 50 l. plastic bins using phytoplankton film collected from the brackishwater ponds. Since then the NPCL has developed methods of mass rearing of *Penaeus indicus* larvae using modified Galveston system. Appropriate live feed cultures have also been developed. I would like to use this occassion to give a brief account of these efforts.

Following a modified Galveston type hatchery system, mass production of *P. indicus* seeds commenced at the NPCL in 1980. The spawning is carried out in small indoor plastic pools of 500 l. capacity and newly hatched nauplii are transferred to 2000 l. capacity plastic line pools (@ 50/l) where the rearing is carried out. In simultaneous operations separate batch cultures of mixed phytoplankton predominated by the diatom *Chaetoceros* sp. and continuous cultures of the rotifer *Brachionus plicatilis* and the cladoceran *Moina* sp. are maintained in the laboratory. The seawater (Salinity 32 ± 2 ppt.) is previously pumped into large containers where it is allowed to settle for 2 days after which it is filtered through a 60 micron mesh nylonbolt cloth before use in the culture operations. From last nauplius stage onwards (2nd day after spawning) 200 l of mixed phytoplankton culture predominated by *Chaetoceros* (200,000 cells/ml) is pumped into the culture tank after reducing equal quantity of water from it every day. The protozoea stage onwards

the larvae begin to feed on diatoms. When the larvae transform into mysis, in addition to this feed, frozen *Brachionus plicatilis* is also provided as food at the rate of 100 rotifer per larvae per day. Feeding of diatom is discontinued when the larvae metamorphose into postlarvae. At this stage frozen cladoceran *Moina* sp. is provided as food at the rate of 20 per postlarva per day. Five days after they become postlarva they are harvested and counted before stocking in a nursery.

Vigorous aeration of water is provided throughout the rearing period and constant check is made on the quality of seawater used. From nauplius to postlarvae an average survival rate of 70% is achieved through this process. The number of batches and the amount of *P. indicus* seeds (PL20) produced at the NPCL is given in table-1.

Table - 1.

P. indicus seeds produced at Narakkal Prawn Culture Laboratory

Year	No. of batches	Seed produced PL 20 ($\times 10^7$)	Seeds distributed to farmers ($\times 10^6$)
1980-81	27	1.6	0.5
1981-82	41	1.2	0.28

From late 1981 onwards the mariculture facility of the CMFRI at Kovalam, Madras has started producing seeds of *P. monodon* by following this system using plastic lined pools of 10,000 l. capacity.

The advantage of this system is that it has used the culture of the diatom *Chaetoceros* which is easy to develop under local conditions and attains high concentration in short time. Besides, it has completely obviated the use of brine shrimp nauplii to feed the mysis stage upwards by substituting with easily culturable *Brachionus* and *Moina*.

It is well known that the key factor of the successful hatchery operation for production of prawn seeds is the availability of appropriate feed for the larval prawns and it is this factor that makes it a complicated operation. Developing and maintaining phytoplankton and zooplankton cultures require technical expertise with the result these practices have not come to the level of the common man. For a long time, attempts made to rear prawn larvae using compounded feeds have not been very successful. The recent works of Hameed Ali (1980), Hameed Ali and Dwivedi (1977) and Alikunhi *et al.*, (1980) has shown that successful rearing of prawn larvae in large quantities can be achieved through the use of prepared feed made out of finely ground tissue of crustaceans held in suspension in the culture medium.

Hameed Ali (1980) successfully reared larvae of *P. merguiensis*, *Penaeus* sp. and *Metapenaeus monoceros* in plastic pools using a tissue suspension made out of freshly ground *Acetes* species. This method, no doubt, is an improvement over the others as it obviates the need of elaborate set up of phytoplankton cultures and the *Artemia* nauplii. In the experiments conducted at Jepara, Indonesia he prepared this diet from frozen and stored blocks of *Acetes* sp. by a process of

blending the same with saltwater, boiling, decanting and sieving through different mesh nylon netting. He used 50 to 160 micron size particles of this material for zoea and 250 to 400 micron size for mysis and early postlarvae. This feed held in suspension is broadcast over the hatchery pool at 5 hourly intervals at the rate of 2 to 3 times the weight of the larvae initially and increasing the feed by 50 to 70% subsequently. In these experiments which are mostly carried out in 1.78 tonne capacity plastic pools, slow exchange of 15 to 25% of water was made after the larvae reached the mysis stage and also when too much of provided food remained unconsumed in the medium. By this method he produced 475,732 post-larvae of *P. merguiensis* (survival 48.4%), 21,374 post-larvae of *Penaeus* sp. (survival 97.16%) and 76,583 post-larvae of *Metapenaeus monoceros*. This method of rearing is particularly noteworthy as relatively high production rate, as much as 58,390 postlarvae per m^3 of seawater, is attained in the experiment conducted in a pool of 6 m^3.

This method of rearing has been further extended by Alikunhi *et al.*, (1980) who used ground tissue (in suspension) of juvenile penaeids and the stomatopod *Oratosquilla nepa* in the regular commercial hatchery operation at the Regional Shrimp Hatchery at Azhicode, Kerala for rearing *P. indicus, P. monodon, P. semisulcatus, M. monoceros, M. dobsoni and Parapenaeopsis stylifera*. The feed preparation and feeding has been further refined. The artificial feeding started as soon as the nauplii moulted into the first zoea stage when particle size of feed given was 50 to 150 microns. This was increased to 200-300 microns for I and II stage mysis and to 400 micron for III stage mysis and early postlarva. The Regional Shrimp Hatchery produced over 3 million postlarvae of *P. indicus* in 1979 and 1980 in addition to smaller quantities of other species. The survival rate attained by the hatchery in the case of *P. indicus* was 20% in 1979 and 20% in 1980.

As indicated earlier the successful use of a prepared wet feed stuff that could be used from off-the-shelf in rearing prawn larvae is certainly a step forward towards development of prawn culture even if the preparation of the same involves technical skill. Let us hope that the researches being carried out in the various laboratories and the trials in the hatcheries will soon develop a suitable and efficient dry feed stuff that could be dispensed from shakers for rearing prawn larvae in mass quantities. Such a development only can bring the prawn culture operation to the level of common farmer.

Factors considered important for successful larval rearing

Technology for mass production of prawn seed is now available and I am sure, whether one method or the other is used, this technology will get refined and improved in efficiency during the course of practice. Now let us identify and consider various factors responsible for successful hatchery operations for large scale seed production.

Water quality:

The quality of the seawater to be

used for spawning and larval rearing is the most important among these factors. Clean unpolluted seawater with no suspended impurities is essential for the operations and this should be the foremost consideration in the selection of site for hatchery. In almost all the hatcheries the seawater is taken in for use only after filtration which may be effected through various means such as elaborate fast or slow sand filters or simpler system of settling and filtering through suitable mesh cloth filters or even by introducing simple mechanical filters in the water inlet system of the pumps. The actual type of filter system to be used can only be determined after the water quality is assessed but it should aim at removal of all suspended matter and such planktonic elements which are likely to develop, multiply or bloom subsequently.

Hudinaga and Kittaka (1975) found that hatching and survival rates of the larvae were affected by biological differences between the seawater from different regions. Significant differences in the survival of the larvae of pink shrimp cultured in bay waters and oceanic waters was observed by Ewald (1965). He found that oceanic waters always gave better results. At the NPCL we observed that seawater containing large numbers of ctenophore, *Pleurobrachia* sp. is unsuitable for larval rearing even when they are removed by filtration.

Several workers have used EDTA (Ethylene diamine tetra Acetic Acid) to enhance the quality of seawater used for spawning of prawns and for larval rearing. Cook and Murphy (1969) added 1 gm. of sodium salt of EDTA to every 100 litres of the rearing medium to avoid catastrophic mortalities. Cook (1970) found that the larvae of *P. aztecus* survived well in 24 ppt salinity with EDTA but suffered complete mortality without it. Philippine workers (Anon 1976a & b) also added EDTA at the rate of 0.5 gm/1000 litres/day in the large outdoor concrete tanks of large scale production of prawn fry. Seawater used for larval cultures by Beard and Wickins (1980) was treated with EDTA (at the rate of 0.1 gm/100 litres) and vigorously aerated 24 hours before use. EDTA is a metal chelator and has been used successfully in phyto cultures also. The beneficial effects of this addition of EDTA is still not well explained.

The temperature of the water is another parameter which has definite influence on successful spawning and rearing of the larvae. 28° C $\pm$ 2 is considered as suitable water temperature for hatchery operations by many workers. That lower temperatures retard the development of the eggs and larval stages and conversely the higher temperatures accelerate such processes is well known. Lee and Lee (1968) found that at a given temperature the eggs of most of the penaeid prawns take approximately same time to hatch out. Muthu *et al.*, (1978) observed that this is due to similarity in the quantity of yolk stored in the eggs of different species and that the variations in the size of eggs of different species is due to the difference in the size of perivitelline space. In the nauplius stage of the larvae the development is mainly controlled by the

temperature of the medium. The effect of temperature on development becomes reduced when the larvae start feeding i. e. from protozoea onwards.

Temperatures ranging from 24° C to 32° C have been found to be suitable for the development of penaeid larvae (Hudinaga, 1942; Cook and Murphy, 1969). In the experiments conducted at NPCL temperatures below 24° C have created low survival and sometimes even total loss of stock particularly when the larvae are in the lower stages of development.

The salinity of the water exercise profound influence in the development of prawn larvae. Hudinaga (1942) found that salinities ranging from 27 to 34 ppt was suitable for development of penaeid larva. Survival of the larvae of *P. aztecus* was best at 28 to 30 ppt and at 34 ppt the survival was relatively poor (Cook, 1970). Beard *et al.* (1977) found that gradual reduction of salinity to 25 ppt by the time postlarval stage is attained was beneficial in rearing the larvae of *P. merguiensis*.

At the NPCL successful spawning and rearing of the larvae of most of the species of penaeids have been carried out in seawater of salinities varying from 27 to 34 ppt. But the best result have been obtained in salinity range of 28 to 34 ppt. Even partial exchange of water with another batch of water with variation of salinity of 2 ppt. was injurious to larvae in early stages. Light intensities below 1000 lux inhibited normal development of protozoea of *P. kerathurus* and prevented their metamorphosis to mysis stage (Lumare *et al.*, 1971). But Cook and Murphy (1966) found that the larvae can also be reared in the dark and that light is not essential for their development. According to Kurata and Shigueno (1979) adequate light intensity is necessary for successful rearing and that the postlarvae reared outdoors was healthier in appearance. Hameed Ali (1980) and Alikunhi *et al.*, (1980) carried out their experiments outdoors but covered the culture tanks with tarpaulin to reduce excess sunlight. My own experience at NPCL is that better growth and survival of larvae was obtained in the rearing pools kept in the glass house exposed to bright sunlight. Production of diatoms in the pools is enhanced due to exposure to sunlight.

Higher values of pH in the culture medium (8.5) was reported to be inimical to protozoea of *P. japonicus* (Furukawa, 1969) and caused large scale mortality and abnormalities in development. In the open community method of larval rearing heavy mortality was reported due to increase of pH upto 9.0 following blooms of phytoplankton. This malady was often experienced during the experiments at the NPCL and care was taken to see that the pH never exceeded 8.2 in the culture tanks.

Accumulation of ammonia and nitrites in the culture medium is toxic to the animals. Here again, precise level of toxicity of these metabolites to penaeid larvae is not clearly known. Cathedral *et al.*, (1977) found that tolerance of *P. monodon* larvae to these metabolites increased as they grow older. Collection of information on the long term and short term effects of these metabolites on prawn larvae is urgently needed particularly since we are planning to put up

large number of hatcheries throughout the country for production of prawn seeds.

Larval rearing and feed

Prawn larva starts feeding from the protozoea stage onwards. The breakthrough in culture of prawn larvae happened in 1942 when Hudinaga successfully used pure cultures of the diatom *Skeletonema costatum* to feed protozoea. *S. costatum* remained as the classical food of prawn larva for a long time. Later Hudinaga and Kittaka (1967) and Fujinaga (1969) showed that prawn larvae can survive equally well by feeding on mixed cultures developed in concerte tanks by fertilizing with inorganic fertlizers. Cook and Murphy (1969) used pure culture of *Skeletonema costatum, Thalassiosira* sp., *Cyclotella* sp., *Phaeodactylum tricornutum, Dunaliella, Exuviella, Gymnodinium spendens* and *Isocrysis galbana* and found that only *Isocrysis galbana* was unsuitable for the purpose. Several other species of diatoms like *Chaetoceros gracilis, Coscinodiscus granii, C. centralis* and *Cylindrotheca* were also used by different workers either as pure cultures or as mixed cultures to feed prawn larvae in their early stages. (Anon, 1977; Kurata and Shigueno, 1979; Beard *et al.*, 1977; Aquacop, 1975, 1977; Salser and Mock, 1974).

Several prepared feeds have been tried and among these the bread yeast used by the Philippine workers, finely powdered soyabean cake by Hirata *et al.*, (1975), a formula feed of Kurata and Shigueno (1979), powdered fat free rice bran used by Ishida (1967), activated sludge used by Imamura and Sugita (1972), marine yeast used by Furukawa, (1973) washings of filamentous algae and juice of Sargassum (Anon, 1976a) and fermented extract of vegetable refuse from kitchen and egg yolk (Anon 1977) have given fair amount of success. The latest among the prepared feeds used are the microencapsulated feeds used by Jones *et al.*, (1979), tissue suspension of *Acetes* and *Mesodopsis* used by Hameed Ali (1977) and Hameed-Ali and Dwivedi (1980) and similar suspension of juvenile prawn and squilla meat used by Alikunhi *et al.* (1980). Different sized particles of this feed have been used for the different stages of development.

For the mysis and early postlarval stages the classsical brine shrimp nauplii has been the accepted food for a long time. Shigueno (1975) made trials with replacing this with easily cultured *Brachionus,* chopped and washed mussel and clam meat and formula feeds. Frozen *Brachionus* has been found suitable for feeding mysis by Platon (1978) and by the Scientists of the NPCL. Similarly frozen cladoceran *Moina* has been successfully used at the NPCL for feeding postlarval stages. The free living nematode *Pangrellus* has been used to feed the mysis stages of *P. semisulcatus* and *M. stebbingii* in Israel by Samocha and Leweinsohn (1977).

Postlarval rearing

The general practice in hatcheries is to harvest the larvae at the stage of PL-4-5 as they are found to become overcrowded in the containers and acquire cannibalistic tendencies. In nature this is the stage in which they seek the protection of the coastal water and make their entry to estuaries. Postlarvae at

this stage are quite hardy and can be transported to farmers' nurseries without difficulty. The closed system of raceway described by Mock *et al.* (1973) is quite efficient in rearing them at high densities of 2300/m² (22mm) and 26000/m² (6mm) with over 90% survival. In a recent experiment at the NPCL 16000 PL–5 stocked in a 6m² cement tank fitted with an external biological filter resulted in 96.5% survival when harvested at 18 mm size (PL–20). Only formula feed was used for feeding.

Diseases

Data on the diseases affecting the larval forms of Penaeids in the hatcheries is scanty. Fungal infection caused by a species of *Lagenidium* is reported by Lightner and Fontaine (1973). This malady is often noticed during the experiments at the NPCL where the stock was abandoned and facilities disinfected when such occurrences happen. "White turbidliver" disease has been reported to have caused heavy mortalify in *P. japonicus* larvae (Momoyema, 1974). This disease is attributed to the bacteria *Vibrio* sp., and so also another disease reported by Shigueno (1975) causing loss of parts of appendages of larvae. In the initial stages of this disease the nervous system of the larvae develop yellowish vermillion and red colours. Frequent attack of the fungus *Langenidium* has been reported at the SEAFDEC hatchery in Philippines (Anon, 1977) where 1 ppm formalin has been used to treat the affected larvae. This treatment has not given good results at the NPCL.

Conclusion

Considerable progress has been achieved in rearing prawn larvae under controlled conditions in India and abroad. Based on these results commercial production of prawn seeds have commenced in hatcheries in different parts of the world. Recognising the need for large quantities of prawn seeds for developing aquaculture in coastal regions of India various agencies concerned are planning to establish prawn hatcheries. While the technology developed in this regard is suitable to run commercial hatcheries, it should be the endeavour of the research organisations to carry out planned research on different aspects of prawn breeding and larval rearing in order to find new and more efficient systems. Special attention may be given to simplify the procedures involved to develop small scale units using locally available material so that the farmers themselves could manage a hatchery for their own requirement of prawn seeds.

There are many aspects of this technology which call for immediate attention of the scientists both from the standpoint of basic and applied research. It is well known that the development of appropriate larval feed is the key factor in mass rearing of the prawn larvae. The live feeds, the prepared feeds and the formula feeds are, no doubt, successfulin varying degrees but they have all been developed on the basis of experience gained in rearing other species by research workers from materials of different kinds. It is possible that a detailed study of the feeding and food habits of the larvae in its natural environment will give us a better understanding of the problem. It is also

necessary to study the details of the feeding mechanism of the larvae in relation to the development of mouth parts and appendages.

Major part of the activities concerning prawn seed production in India is centred around Kerala where the prevailing monsoon makes it impossible to have year round production in hatcheries. The coastal sea water gets diluted and polluted with all the materials poured into it by the rivers in spate during monsoon. This situation can be met only by holding large quantities of sea water in storage in good season and having it used and reused with the help of appropriate water treatment measures. Such facilities are in existance elsewhere and it should be possible to develop and use such facilities here with advantage. Similarly use of automated feed dispensing arrangements as is used in developed countries can help minimise human errors and save labour.

Diseases affecting larval stock and measures to control them are fields in which very little information is available at present. It is desirable to give more attention to this aspect by the researchers and hatchery operators.

In the context of developing prawn culture in coastal areas, for which national priority is given, greater thrust is needed for transfer of technology programmes. The regular training programmes conducted by the Farm Science Centre (KVK) at Narakkal, the *ad hoc* training programmes conducted by various agencies and the Summer Institutes are no doubt helpful in transferring the tecenology to the farmers. More inputs in this direction will accelerate the process of development of prawn culture in the country.

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Appendix 1. List of species of penaeid prawns in which spawning has been carried out under controlled conditions.

Species	Country	Authors
Penaeus japonicus	Taiwan	Huang *et al.*, (1969)
P. teraoi	Japan	Liao and Huang (1973)
	Taiwan	Hudinaga (1942)
P. latisulcatus	Japan	Shokita (1970)
	Australia	Pownall (1974)
P. aztecus	U. S. A.	Cook and Murphy (1969); Cook (1969)
	Tahiti	Aquacop (1977)
P. duorarum	U. S. A.	Ewald (1965); Cook and Murphy (1969); Tabb *et al.*, (1972); Krantz and Norris (1976).
P. kerathurus	Italy	Lumare *et al.* (1971)
	Spain	Rodriguez (1975)
P. marginatus	Hawaii	Gopolakrishnan (1977)
P. stylirostris	Tahiti	Aquacop (1977)
P. schmiti	Venezuela	Pinto and Ewald (1974);
	Cuba	Perez and Saurez (1979)
P. vannamei	Tahiti	(Aquacop 1977)
P. orientalis	Japan	Oka (1967 a and d)
	Korea	Kim (1967)
P. indicus	Philippines	Anon (1976b)
	India	Muthu *et al* (1977, 1978 a)
P. merguiensis	India	Raje and Ranade (1972a)
	Thailand	Ruangpanit *et al.*, 1971)
	Tahiti	Aquacop (1975, 1977)
	U. K.	Beard *et al.*, (1977)
	Indonesia	Hameed Ali (1980)
	Philippines	Platon (1978), Motoh & Buri (1979)

Species	Country	Authors
P. monodon	Taiwan	Liao *et al.*, (1969a)
	Tahiti	Aquacop (1975, 1977)
	Philippines	Villaluz *et al.*, (1969); Anon (1976a); Platon (1978); Motoh (1979)
	Thailand	Kungvankij (1976)
	India	Silas *et al.*, (1978)
P. semisulcatus	Taiwan	Liao and Huang (1973)
	Israel	Samocha and Leweinsohn (1977)
	Thailand	Kungvankij (1972)
	India	Devarajan *et al.*, (1978)
P. esculentus	Australia	Fielder *et al.*, (1975)
Metapenaeus dobsoni	India	Thomas *et al.*, (1976b); Silas and Muthu (1977); Muthu *et al.* (1978b)
	Kuwait	Enomoto (1971)
M. affinis	India	Thomas *et al.* (1976a); Silas and Muthu (1977); Muthu *et al.* (1978c)
M. monoceros	India	Raje and Ranade (1972b); Silas and Muthu (1977); Mohammed *et al.* (1978)
M. ensis	Japan	Funada (1966)
	Taiwan	Liao *et al.* (1969b)
M. joyneri	Korea	Lee and Lee (1968)
	Taiwan	Liao and Huang (1973)
M. burkenroadi	Japan	Kurata and Pusadee (1974)
M. stebbingi	Israel	Samocha and Leweinsohn (1977)
Parapenaeopsis stylifera	India	Thomas *et al.* (1975); Silas and Muthu (1977); Muthu *et al.* (1978b)
Artemesis longinaris	Argentina	Boschi and Scelzo (1974)
Hymenpenaeus mulleri	Argentina	Scelzo and Boschi (1975)

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PRAWN SEEDLING PRODUCTION - STATE OF ART

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Introduction

Prawn is the principal food item of export from India. In the recent past the quantity of prawn catches from the sea has not increased significantly. As a result, the Marine Products Export Development Authority, Ministry of Commerce and traders are anxious to develop alternate methods to sustain and increase the prawn exports. Therefore the culture of prawn is being given higher importance.

In the last three decades extensive studies on the taxonomy, biology and ecology of commercially important prawns have been carried out. The techniques of shrimp culture have been evolved and developed by National Fisheries Research Institutes and few Agricultural Universities. The prawn seed required for culture purpose was being met from the collection of seedlings from the natural resources. However, the seed availability fluctuates during different months in different conditions. In this direction, the Central Institute of Fisheries Education (CIFT) made an effort to build "Prawn Seed Banks" under various programmes.

For the development of shrimp culture, dependable sources of shrimp seedlings are very much felt. The breeding of prawn in the laboratory under controlled condition have been started by traditional Universities, Agricultural Universities and Fisheries Research Institutes of Indian Council of Agricultural Research (ICAR) namely Central Marine Fisheries Research Institute, (CMFRI), Central Inland Fisheries Research Institute (CIFRI) and Central Institute of Fisheries Education. Each Institute has come out with a methodology supported by publications that they are able to breed prawn successfully.

The ICAR Institutes are of the view that the prawn breeding technology is available in India and there is no necessity to import the technology from other countries. At the instance of the Planning Commission, Lever Bros. also made an effort to develop prawn hatchery complex, near Madras; but the work has not progressed to the stage of commercial production due to few difficulties.

Amongst the private entrepreneurs, a distinguised Scientist has started a prawn hatchery "Crescent Hatchery and Prawn Farm" at Eriyad, Kodungallur, Kerala. This hatchery has bred *Penaeus indicus*, *P. monodon* and *Macrobrachium rosenbergii* and the seeds of these species are sold to private

organisations (Personal Communications).

Work carried out at CIFE, Bombay

The CIFE, Bombay initiated studies on prawn hatcheries and seed production during 1977 at Bombay. Based on the preliminary studies, modifications were effected in the breeding and rearing techniques especially in developing suitable feeds for different stages of Prawn larvae (Dwivedi and Iftekhar, 1979, 1980., Hameed Ali and Dwivedi 1981).

The prawn hatchery was established at CIFE Brackishwater Fish Farm, Kakinada during 1978. The breeding of *P. monodon*, *P. indicus* and *Metapenaeus dobsoni* have been successfully done. The CIFE has initiated a pilot project in establishing a prawn hatchery at Okha, in collaboration with the Department of Fisheries, Government of Gujarat in 1979.

The breeding of *P. merguiensis* was successfully achieved and reared upto PL 8 at Bombay. Besides *P. merguiensis*, *Parapenaeopsis stylifera* and *Metapenaeus affinis* were also induced to spawn as a part of teaching programme and were successfully reared. About 3.34 lakh larvae reared upto harvestable postlarvae size. Part of the stock was sold to private entrepreneurs in and around Bombay and Goa. The brood stock was obtained from the natural grounds.

Hatchery Design

Various designs have been developed for prawn hatchery. The tanks used for hatching the eggs vary in size, shape and material. In the Japanese hatchery system RCC tank of 57m³ and 200m³ were used. These tanks have an overall length of 4.2 m x 7.6 m x 1.8 m and 10 m x 10 m x 2 m. All the tanks had a gentle slope to facilitate drainage (Shigueno, 1969).

At Galveston laboratory, Texas, Cook (1969) has used 946 l. capacity fibre glass tanks, containing 560 l. of water. The bottom dimension of the tank are 90 x 152 x 61 cm. Whereas the top dimention are 110 x 168 cm. Dwivedi and Iftekhar has used 300 l. cylinderical plastic pools/LDPE containers for spawning. The rearing was done in large sized cylindrical or rectangular containers of 1450/2000 l. capacity. (Figs. 1, 2, & 3). At Azhicode, Alikunhi *et al.* (1980) has used all types circular plastic containers of varying capacities ranging from 1.75 tons to 10.5 tons.

Keeping in view the extension of brackishwater farming, Philippines have designed the hatchery by scaling down the hatchery technology from large tanks to a level which can be adopted by the private sector, especially in the villages with a minimum of financial and technical inputs using 2 tons capacity rearing tanks made up of marine plywood shaped into a cylinder with octagonal cross section and conical bottom, coated with an epoxy paint at its inner side (Platon, 1978).

Limiting factors

In a culture system, the density of the larval stock depends on several factors, of which food, temperature and salinity are the most important (Cook and Murphy, 1969). During the course of experiment three different types of containers were used for rearing the

larval stages. In the Instance of breeding on board the vessel, 90 litre plastic buckets and in the laboratory 300 litre polyethelene cylindrical containers were used. Gravid females were induced for spawning following the methoddescribed by Cook and Murphy (1969). The nauplii were not disturbed. During zoea stages the content of 90 litre capacity containers was shifted to 300 litre capacity containers.

The protozoea larvae were further shifted to 1450 l. capacity rectangular or 2000 l. capacity cylindrical containers for further development. Results of the rearing experiments are given in Table 1.

Temperature

Temperature seems to affect the rate of development of the larval shrimp. The larval moulting rate was faster during summer when the temperature range was from 27.1 to 29.5°C and it was slow during winter when the temperature range was 22.5 to 24°C. The above observation is in confirmity with the observation made by Cook and Murphy (1969). It took 38 hours to reach protozoea-1 from nauplius-1, when the average water temperature was 28.3°C. The moulting rate dropped considerably when the temperature was recorded at 22.8°C and approximately 90 hours were taken to reach protozoea-1. Survival upto Zoea at both experiments was 38.24 and 86.68%.

From protozoea-1 to Mysis-1 the time taken was 118 hours compared to 207 hours when the average water temperatures were recorded as 27.1°C and 22.5°C respectively.

From Mysis-1 to post larvae the time taken was also high. It took 146 and 189 hours when the temperatures were 27.2°C and 24°C respectively. The survival rate at both the temperature was 7.97 and 80.27% for mysis stage and 30.29 and 43.22% for postlarvae. (Flow diagram 1).

Salinity

No appreciable difference in the salinity was allowed during the experiments. Everyday while changing the water, care was taken to maintain the salinity by flushing freshwater in the culture medium.

Feeding

Apart from changing the water everyday, artificial feeds were also given from Protozoea-1 stage onwards. During Protozoea stages egg custard was fed at the rate of 0.08 gm/ml/l or 2 ml for one thousand larvae. For mysis stages a tissue suspension of *Acetes* (a sergestid shrimp) was administered at a feeding rate of 1-2 g/ml/l or 4 ml per thousand larvae. The same was continued to post larvae too and they were further supplemented with separate cultures of rotifers or *Moina* sp. at the rate of 100–150 individuals/larva/day.

Bottlenecks

A number of experiments conducted at Okha were forced to be discarded due to frequent parasitic attacks during larval rearing. Nearly in all the experiments infection occured due to *Ephelota* sp. a suctorean parasite. The protozoan was found to attack during Protozoea stages.

Infection was initially restricted at the caudal setae of the protozoea larva.

During the early stages the host was found to be normally active. The host constantly gives violent kicks, probably to get rid of the parasite, but due to constant attachment of the parasite by its hooks it becomes impossible for the host to remove the parasite thus after loosing lot of energy for getting rid of the parasite the host becomes passive. Thereby gives a chance to the parasite to enter the whole body. The intensity of infection increases manyfold during moulting from Protozoea II to III.

The hatchery runs conducted at Bombay were also found to suffer such type of infection but the intensity of infection was controlled by adding one third sea water regularly and also the water quality was maintained during the hatchery runs through filters. The survival at different larval stages are shown in Table 1.

Remarks and Conclusions

A review of work in Prawn breeding and larval rearing by the various Institutions to date brings out a few salient features.

1. Ministry of Agriculture, Ministry of Commerce, Government of India and State Governments are very keen to develop prawn culture and prawn hatcheries in all the maritime states. Financial allocations have been made to this effect by the various agencies.

2. The Fisheries Institutes of ICAR namely CMFRI, CIFE, and CIFRI have evolved and perfected technology of prawn breeding and rearing under laboratory and field conditions.

3. In view of the vide fluctuation of prawn seed in nature over time and space, it is necessary to set up properly organised prawn hatcheries at various centres with adequate facilities and man-power for a production capacity of over 10 million postlarvae using the commercially important species of that area.

4. As in other countries, availability and procurement of brooders is a major problem in India. It is necessary to ensure the availability of brooder and facilities of boats for collection of brooders at appropriate time.

5. The technique of eyestalk ablation has to be perfected with all the commercially important cultivable prawns and pilot projects may be taken up for extensive experimentation.

6. Though the principle used in production of prawn seed is common in all the hatcheries operated by various Institutions the details of the equipment used vary considerably. The equipment used in have been evolved over a period of time. At present scientific norms do not exist and hence cannot supply a ready made hatchery system. The system is usually developed by repeated trial and error experiments and continuous supervision and devotion of the concerned Scientists. As a standardised system of hatchery for commercial operation is not immediatly available, we are not in a position to provide a comparative and proper design for a commercial hatchery. In order to reach the standardisation it is necessary that repeated experimentation should be undertaken and the equipment proposed should be standardised.

7. The efforts of Individual Institutions and Research workers have so far only helped to set up pilot hatcheries. Therefore, drawing conclusions regarding the cost of setting up of commercial hatcheries is premature at the present stage. And as such, at best, we can only compare the cost incurred by different institutions and research workers to produce a given number of prawn larvae. The system developed, is capable of yielding repeated results and the same hatchery can be used for a larger period of time to produce multiple crops. In some cases different species can be used during different seasons. It is necessary that a well-co-ordinated approach should be developed so that hatcheries which are developed are extensively used.

8. A comparative study of the 3 systems of hatchery production of seed under use in India and elsewhere abroad indicates that Indian system is the cheapest and a dynamic in nature. (Hamid Ali, *et al.* 1982)

9. There is an immediate need of extending the technology already developed to the farmers and adequate staff and finance have to be made available in this regard.

10. As an outcome of this national symposium, the MPEDA, Ministry of Agriculture and other Financial Agencies come to a decision to give proper incentives and encouragement to set up commercial hatcheries in the Indian coasts.

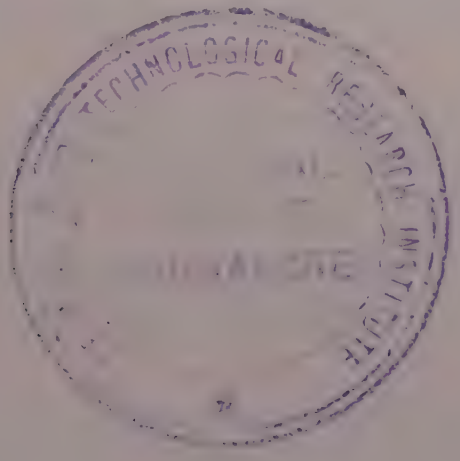

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TABLE — I

Preliminary observations on some Physico-chemical factors at CIFE prawn hatchery, Bombay.

Larval stage	Time in hours Expt. 1 24-4-79	Expt. 2 20-1-79	Average Air Temperature Expt. 1	Expt.2	Average water Temperature Expt. 1	Expt. 2	Average Salinity Expt. 1	Expt. 2	Feeds	Rate of feed/ lit of culture medium	Rate of feed/ per 100 larvae	% survival rate Expt. 1	Expt. 2
Eggs	12	14	28.0	26.5	29.5	24.0	27.0	32.0	—	—	—	—	—
Nauplius	18	24	28.2	26.0	28.0	38.8	24.8	31.6	—	—	—	—	—
Protozoea	38	90	29.5	23.5	28.5	22.8	29.0	31.5	Egg custard	0.08 g/ ml/l.	2 ml	38.24	86.68
Mysis	118	207	28.8	23.9	27.1	22.5	30.2	31.8	Acetes Suspen-tion	1–1.2 g/ml/l	4 ml	7.97	80.27
Post-Larvae	146	189	29.5	26.0	27.2	24.0	30.2	32.0	Acetes suspen-sion, live Zoopla-nktonic forms e. g., *Monia, Brachionus*	1–1.2 g/ml/l	4 ml 100-150 indivi-duals per larvae	30.29	43.22

PRAWN HATCHERY MODEL CIFE - 1978

FLOW DIAGRAM - 1

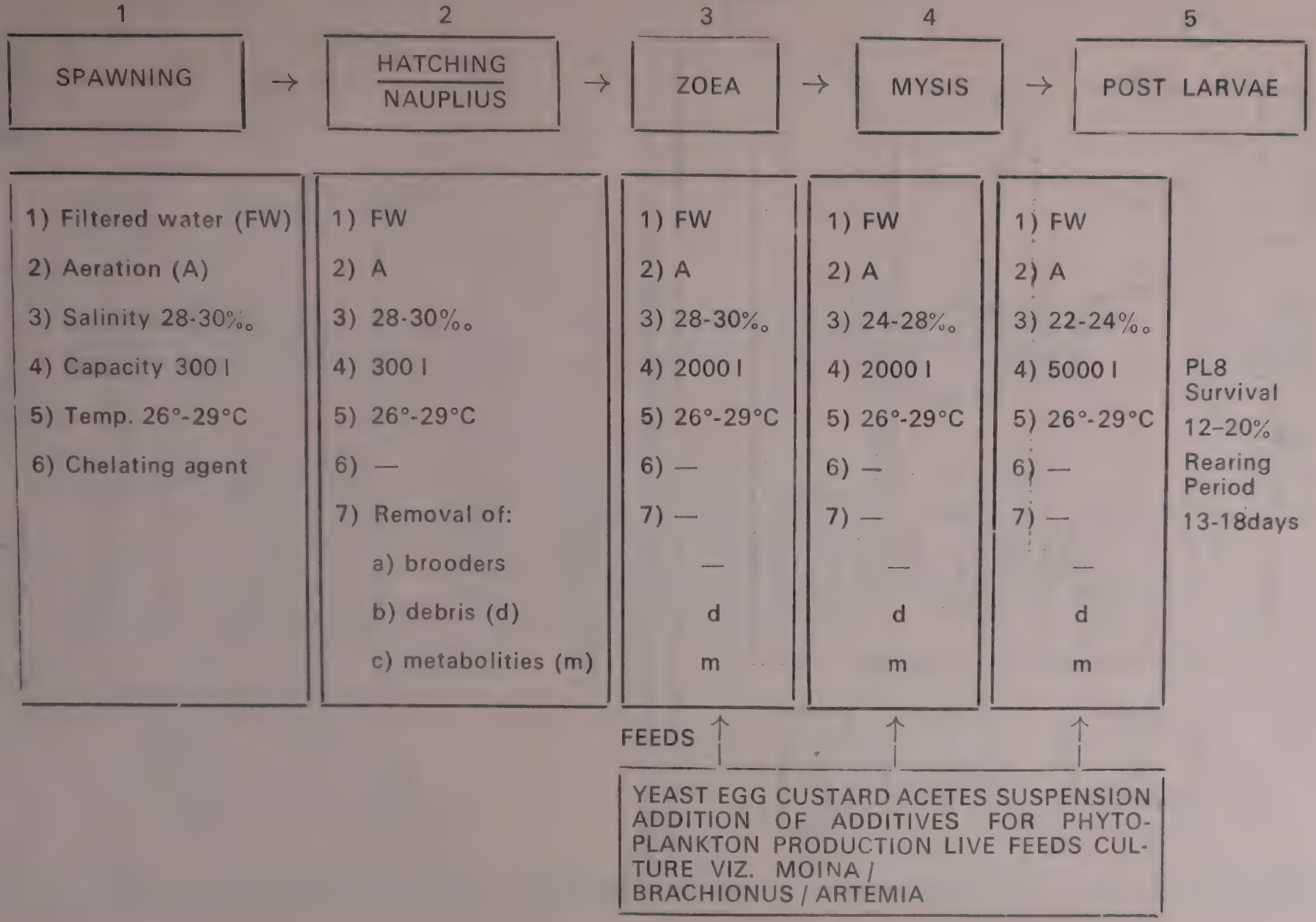
A. VESSEL

Fishing Ground Brooder collectin	Trawling 30 minutes	Brooder Selection 2 X 901	Aeration D. C. 2 PTS 2 X 90	Brooder transport 6, brooders 2 X 901

B. LABORATORY / HATCHERY

SPAWNING	18 hrs.	HATCHERY	38 hrs.	REARING	118 hrs.	REARING	146 hrs.	REARING	13-18 days
EDTA/ TRIPLEX		Nauplius Survival S = 90%		Zoea S = 38-87		Mysis S = 8-80		Post larvae S = 30-48	Post larvae S = 12-20%

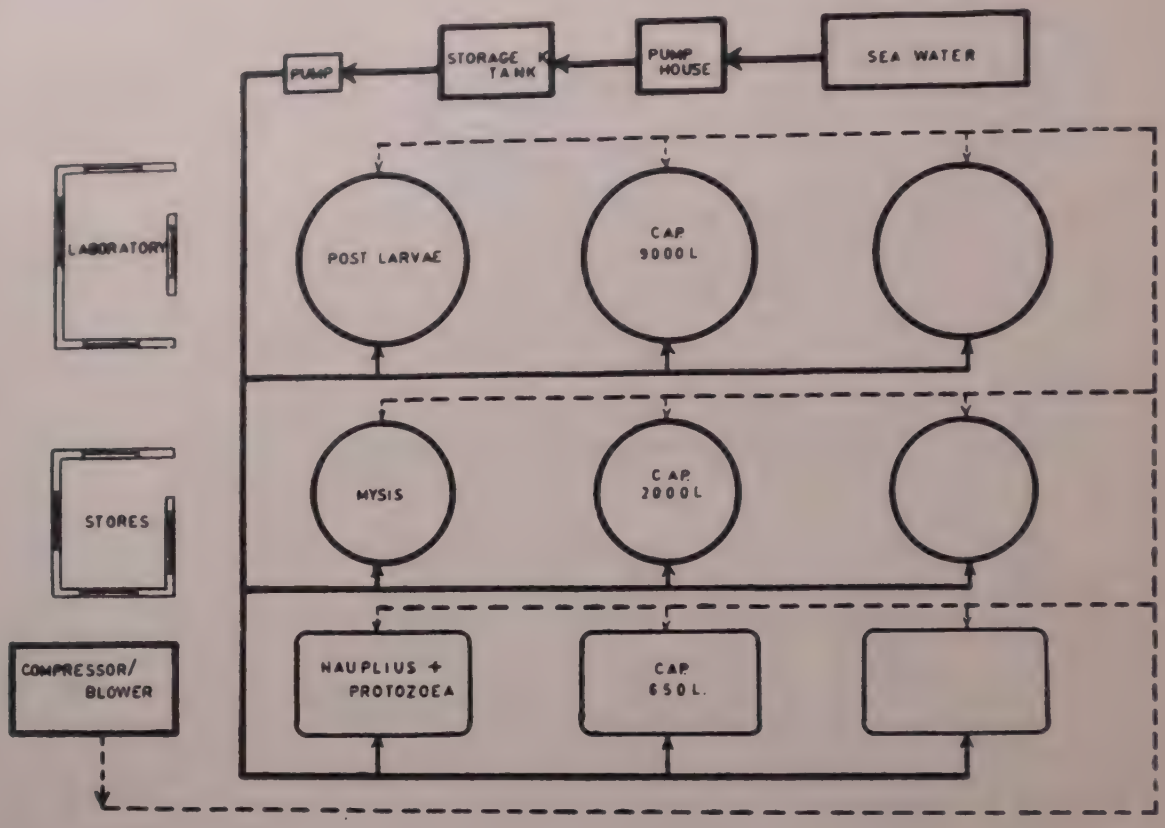
PRAWN HATCHERY
FLOW DIAGRAM 2 – REARING



PRAWN HATCHERY AT OKHA (GUJRAT)

(DIAGRAMATIC LAYOUT)

Fig. 1



PRAWN HATCHERY AT C I F E BOMBAY

(DIAGRAMATIC LAYOUT)

Fig. 2

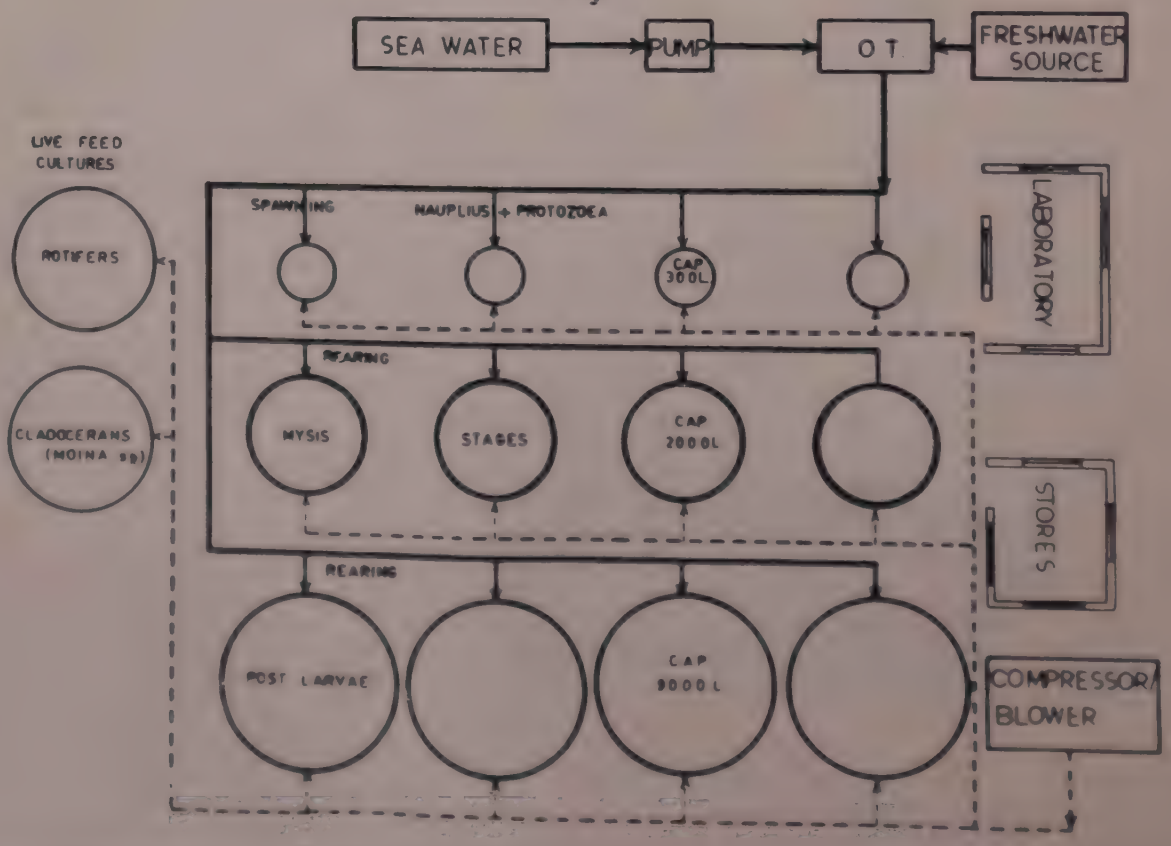
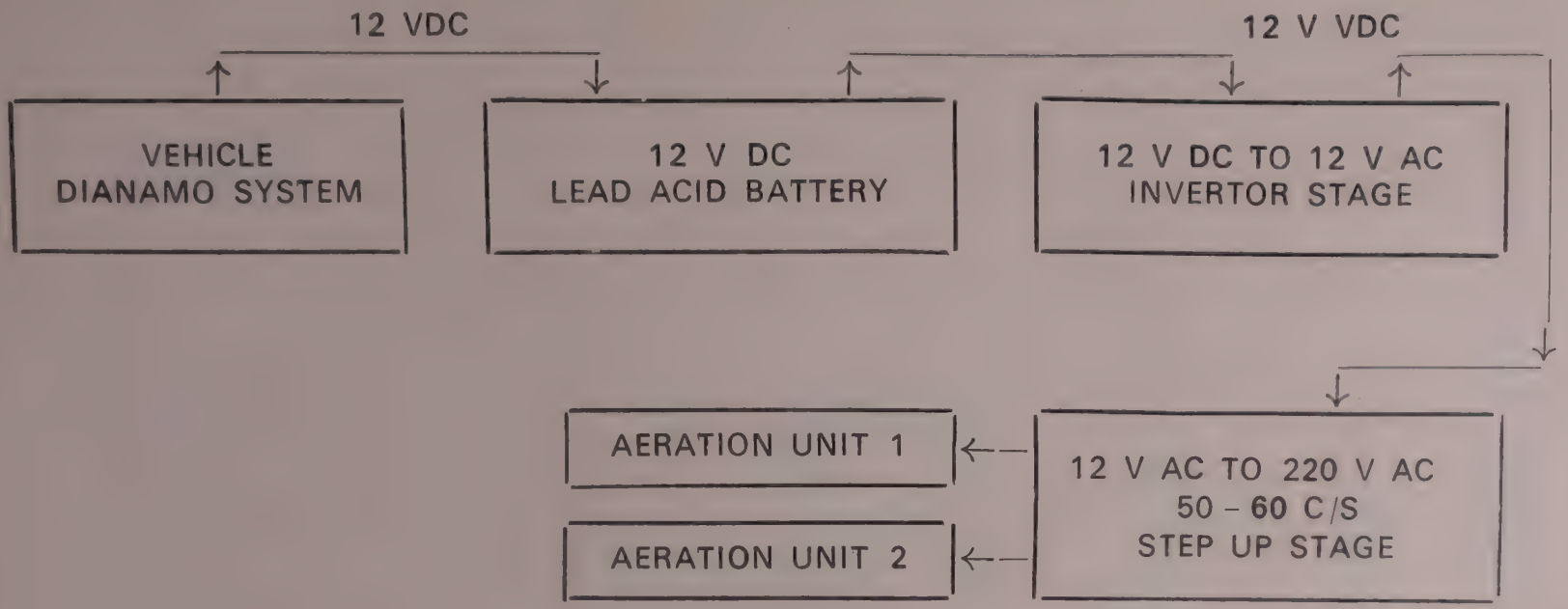


DIAGRAM OF POWER SUPPLY UNIT FOR AERATORS

(12 VDC 220 VAC; 50-60 C S INVERTOR)

Fig. 3.



CIFE AQ - 82-310

POSTER PAPER

INDUCED MATURATION OF PENAEID PRAWNS FOR HATCHERY OPERATIONS

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For successful hatchery production of penaeid prawn seed a steady supply of spawners of desired species of prawns is a necessary prerequisite. As the collection of spawners from the sea is a costly and uncertain operation, efforts have been made to induce the captive broodstock to mature under controlled conditions. The most successful technique in inducing maturation in captivity has been the removal of one of the eyestalk which are known to be the site of production and storage of gonad inhibiting hormones. At the NPCL commercially important species of marine penaeid prawns have been induced to mature and spawn by using the technique of unilateral eyestalk ablation.

Adult *P. indicus* (over 140 mm in TL, 30 mm CL) were collected from the grow-out ponds of the NPCL and kept in 0.3 tonne plastic pools containing filtered sea water of salinity 33 $\pm$ 2 ppt. After 24 hours of acclimatization the females are selected and one eyestalk of each is removed by electro-cauterisation. The ablated females were kept along with half that number of unablated males in 10 tonne, circular plastic lined pools in which the seawater is made to circulate through a sub-gravel filter by air-lifts. The pools were accommodated in an open shed with tiled roof. The prawns were fed *ad libitum* with fresh clam meat. The entire process is carried out in ambient temperature of 28 $\pm$ 2° C the salinity of water is maintained at 32 $\pm$ 2 ppt and the pH at 8 to 8.2.

The prawns matured within 3 to 5 days after eyestalk ablation and 70% of them spawned successfully. The eggs hatched into healthy nauplii which were further reared upto the juvenile stage.

The size of the prawn chosen for eyestalk ablation seems to have considerable effect on the process of maturation. Quality of sea water also seems to be of prime importance in the maturation of these prawns. O

REARING OF PRAWN LARVAE FOR SEED PRODUCTION

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Rearing the newly hatched prawn larvae is the most demanding of the procedures in hatchery production of seeds. Freshly spawned eggs of the penaeid prawn hatch out into nauplii which pass through protozoea and mysis stages before metamorphosing into post larvae. The method followed for rearing larvae of *Penaeus indicus* at the NPCL of CMFRI is given below.

Freshly hatched nauplii are stocked at the rate of 50 nos. per litre in 2 ton plastic lined rearing pools containing settled and filtered seawater of 33 $\pm$ 2 ppt salinity. Continuous oil free air supply is provided. Rearing is carried out in normal ambient temperature of 28 $\pm$ 2° C. Nauplius passes through six developmental stages before transforming into protozoea I stage within two days. From nauplius VI stage onwards freshly cultured phytoplankton dominated by Chaetoceros sp. at the concentration of 2 million cells per ml (separately cultured and maintained in batch cultures) is added as food at the rate of 200 litres per rearing pool. This feed is introduced daily after removal of approximately 1 ton of water from each rearing pool and the volume is made up with fresh filtered sea water. This process is repeated throughout the rearing period. The protozoea start feeding from stage I and successively pass through three substages to become mysis stage within 3–4 days. The mysis are fed with frozen rotifer *Brachionus plicatilis* (a continuous culture of which is separately maintained) at the rate of 100 per larvae in addition to phytoplankton culture. Mysis pass through three substages in 3–4 days and metamorphose into postlarvae. On metamorphosis, the supply of phytoplankton feed is discontinued and frozen cladoceran *Moina* sp. (separately cultured and maintained) is given at the rate of 20 per larvae along with rotifers until the larva reaches postlarva V stage, when they are transferred to the nursery or despatched to farmers for stocking in their nursery ponds. Following this method, the average survival rate of 80% was obtained. ○

POSTER PAPER

LARGE SCALE PHYTOPLANKTON BATCH CULTURES FOR REARING OF MARINE PRAWN LARVAE

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Successful rearing of penaeid prawn larvae depends on the continuous availability of desired species of phytoplankton. A breakthrough in the culture of penaeid larvae was achieved by Japanese scientist Hudinaga when he was able to culture the diatom *Skeletonema costatum* to feed the *Penaeus japonicus* larvae. Phytoplankton culture developed at the Narakkal Prawn Culture Laboratory of CMFRI for large scale rearing of *Penaeus indicus* larvae consisted chiefly of the diatom *Chaetoceros affinis*.

The culture of phytoplankton is carried out in one ton capacity white coloured fibre glass rectangular tanks having a depth of 50 cm. The tanks are placed under a glass roof to provide natural sunlight. The temperature inside the glass house ranges from 28° to 36° C during day time. To start with, filtered seawater is directly pumped into the culture tank and is fertilised with nitrate, phosphate, silicate and EDTA. Continuous oil-free air supply from an air blower is provided through air stones. When the day-time water temperature is above 32° C and the intensity or sunlight exceeds 1,00,000 Lux for a minimum of six hours, *Chaetoceros* sp. dominates in this culture which is used as inoculam for maintenance of batch cultures. Seawater, settled for 2 days and filtered through 30 micron mesh nylobolt is pumped into the culture tanks and enriched with fertilisers as mentioned in order to develop batch cultures. 100 litres of the starter culture is added as inoculam for each batch. Under normal conditions a bloom (2 million cells per ml) is attained when the tanks are exposed to 8–10 hours of bright sunlight. This culture is used for feeding the larvae. Fresh starter cultures are prepared every week in order to ensure the vigour of the culture. ○

CONTINUOUS CULTURE OF ROTIFERS FOR LARVAL REARING OF MARINE PRAWNS

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A technique for the continuous culture of the euryhaline rotifer *Brachionus plicatilis* has been perfected at the NPCL for the mass production of prawn seeds. Double filtered seawater is pumped into a 40 tonne capacity outdoor plastic lined pool and fertilised with groundnut oil cake (200 gm/ton), superphosphate (2 gms/ton) and urea (2 gms/ton). This medium is inoculated the same day with *Chlorella* culture at the rate of 5 litre/ton and on the second day rotifers are introduced at the rate of about 500 per litre. Vigorous aeration is provided continuously and the culture attains a concentration of 4-5 x 10^5 rotifers per litre in 5 days.

Harvesting is done with a hand-net of 60 micron mesh size in the morning hours when they swarm at the surface. About 200 to 250 million rotifers are collected during each harvest. They are concentrated, washed twice with filtered seawater and after mixing with equal volume of 10% glycerin in seawater are frozen into blocks in a deep freezer. This method of harvesting and preservation ensures a ready stock for use at any time.

After continued harvesting, when the rotifer population declines due to their resorting to sexual reproduction, the culture is rejuvenated in the same pool by renewing 1/3 volume of water and by refertilising. This continuous culture with frequent harvesting can be maintained for over 2 months. The resting eggs produced by them during the sexual reproduction are collected from the bottom of the pool and they are dried and stored for future use. ○

POSTER PAPER

CONTINUOUS CULTRUE OF CLADOCERAN, *MOINA* SP. FOR REARING OF POSTLARVAL PRAWNS

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A low-cost method for large scale culture of the fresh water cladoceran *Moina* sp. has been evolved. *Moina* is used in the frozen condition to feed the postlarvae of penaeid prawns reared at the NPCL of CMFRI.

The cladoceran is grown in 2 ton capacity circular plasticlined pools kept outdoors. Fresh water from a well or stored tap water is pumped into the pools and vigorously aerated. Organic fertilizers like cow-dung and groundnut oil cake along with urea and superphosphate are added to the pools. After one day, a culture of *Chlorella* (maintained in the NPCL) is added as inoculam. The following day adult *Moina* from a stock culture kept in the laboratory are added at a stocking density of 1 animal/litre of water. *Moina* population grows rapidly feeding on the *Chlorella* bloom which develops utilizing the added fertilizers and the natural sunlight and reaches a concentration of 30,000 nos/litre in 7 days. There after the *Moina* are harvested every day morning when they swarm at the surface. Harvesting is carried out by skimming the surface water with a zooplankton net after stopping the aeration. They are washed in fresh water mixed with equal volume of 10% glycerol and frozen in a deep freezer into blocks.

In the event of decline of *Moina* population due to continued harvesting half the volume of water is replaced by fresh water and enriched by organic fertilisers to stimulate *Chlorella* bloom. The *Moina* culture revives in a few days and continuity of culture is maintained for over 3 months. The lobster sediment from the old pool which contains the resting eggs of *Moina* is dried and preserved to start new cultures when necessary. ○

STUDIES ON MASS CULTURE OF EURYHALINE HARPACTICOID COPEPOD *AMPHIASCOIDES SUBDEBILIS* (Willey, 1935) UNDER PHASED FERTILISATION TECHNIQUES

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For nutrition of seed of commercially important fishes in freshwater fish seed farms, an essential prerequisite is the adequate provision of mass culture of suitable species of zooplankters in the nursery ponds. This becomes possible by phased fertilisation technique which enhanced mass production of zooplankters such as rotifers and *Moina* sp. within 48-72 hours. Introduction of fish spawn simultaneously yielded a result of 80% survival of fish seed on the average.

In view of the brackishwater fish seed production, the technique of phased fertilisation in production of brackishwater zooplankton was studied, and the present paper deals with mass culture of a euryhaline harpacticoid copepod, ***Amphiascoides subdebilis*** (Willey, 1935) in the water media of higher salinities. Following are the highlights.

The animals tolerated a wide range of salinities from 11°/₀₀ 46°/₀₀ for various durations under the fertilisation of *Vigna* (Cowpea). The optima occurred around 29°/₀₀, 30°/₀₀ and 31°/₀₀ media grades, on the basis of length of survival periods and maximum fecundity. Then 42 unit feeding conditions i. e., fertilisers by permutation and combination out of the organic material sources such as ground nut, *Phaseolus* (Yellow gram), *Vigna*, Wheat, green algal complex (Chlorobium-Photo synthetic bacteria and algae) and sole inorganic substance i. e., single super phosphate were tried at optimum salinities. It was found that the combination of *Phaseolus* + Wheat + Green algal complex was the best and at 4 ppm input rate under optimum salinities maximum productivity of around 4,000 and 27,000 individuals of this species per litre was achieved at the end of 8 and 15 days, respectively. Under aeration the productivity could be enhanced. Further, besides detailed morphological studies, certain observations are also made on thermal tolerance and moulting behaviour. The above studies clearly show that ***Amphiascoides subdebilis*** can be suitably and effectively be used for larval nutrition in coastal aquaculture. ○

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POSTER PAPER

OBSERVATIONS ON REPRODUCTIVE BEHAVIOUR OF MACROSTOMID TURBELLARIAN, *MACROSTOMUM ORTHOSTYLUM* (M. BRAUN, 1885) CORRELATED TO FECUNDITY AND DIFFERENT FEEDING CONDITIONS UNDER VARYING SALINITIES

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Detailed studies were undertaken on various aspects of reproductive behaviour of a planktonic euryhaline Macrostomid Turbellarian, *Macrostomum orthostylum* (M. Braun, 1885). In the first series of experiments an optimum salinity around 9°/$_{oo}$ was chosen to determine comparative fecundity values, using 10 fertiliser items. These, either singly or in combination comprised, *Arachis hypogoea* (groundnut), *Vigna catjung* (cowpea), *Phaseolus aconitifolius* (yellow gram), *Triticum durum* (wheat) *Vigna* and groundnut, *Phaseolus* and groundnut, *Phaseolus* and *Vigna* and wheat. Using groundnut, maximum fecundity was observed during the entire life span of solitary individuals, implying productivity by parthenogenesis. In other combinations fecundity upto a maximum of 48 offsprings was observed.

In the second series of experiments, fecundity of the animals was observed in each of the tolerating salinities ranging from 1 to 24°/$_{oo}$, using three different organic fertiliser combinations such as groundnut, groundnut + *Vigna* and *Phaseolus* and wheat, in lines with the first series of experiments.

Studies have also been made on production of both subitaneous and resting eggs, in the salinity range of 1 to 18°/$_{oo}$ using six fertiliser combinations. Resting eggs were generally produced at 3°/$_{oo}$ and 11°/$_{oo}$. Detailed studies have also been made on hatchability of resting eggs on desiccation for various periods. ○

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FURTHER OBSERVATIONS ON THE MASS CULTURE OF A SPECIES OF MACROSTOMID TURBELLARIANS, *MACROSTOMUM ORTHOSTYLUM* (M. BRAUN, 1885) UNDER VARYING SALINITIES AND FEEDING CONDITIONS

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This paper deals with the salinity tolerance correlated to mass culture of a euryhaline planktonic species of Turbellarians, *Macrostomum orthostylum* (M. Braun, 1885). As explained in the previous poster paper, the phased system of fertilisation was suitably applied in production of zooplankton in brakish-water environments with encouraging results. Studies were also made on the effect of fertilising the media using four organic fertilisers such as *Vigna catjung* (cowpea), *Arachis hypogoea* (groundnut), *Phaseolus aconitifolius* (yellow gram), Groundnut + *Phaseolus* + *Triticum durum* (wheat). In relation to these feeding conditions, simultaneous observations were made on salinity tolerance. Survival upto a maximum of 112 days was observed in the initial salinities ranging from 1-15°/$_{oo}$. From 16 to 24°/$_{oo}$ salinities the animals survived upto a maximum of 11 weeks. In the salinities around 25°/$_{oo}$, the survival decreased, and at 27°/$_{oo}$ and above salinities total mortality within a day was observed.

In regard to fertilisation, the soluble portion upto 3-4 ppm per litre 48 hours in cultural media were tried. Among different fertilisers, groundnut oilcake and its combination promoted maximum longevity of the animals. At 3 ppm/l. dose, longevity of the animals improved in case of *Phaseolus* and its combination as against 4 ppm/l dosages. ○

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POSTER PAPER

COMPOUNDED FEEDS FOR POSTLARVAL REARING OF MARINE PRAWNS

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Availability of appropriate feed has been the main constraint for rearing the various stages of prawn larvae. This is largely overcome by the use of live feed cultures. But the maintenance of these live feed cultures require specialised technical inputs, labour and time. Compounded feeds have been tried for rearing prawn larvae with varied success in different countries of the world. Attempts are being made to develop compounded feeds for rearing different stages of prawn at the NPCL. One of the successful feeds developed for the post-larval rearing has been described here.

Several feeds were prepared and pelletized with protein contents ranging from 30 to 60%, using clam meat, groundnut oil cake, fish meal, mantis shrimp *(squilla)*, trash fish, yeast and cassava (tapioca). The feeds were prepared by mixing dry powdered ingredients with 50% water and steaming for 15 minutes. The homogenised wet dough was extruded in 1 mm diameter pellets and dried in oven at 70 $\pm$ 2° C for 12 hours. The dry pellets are stored in polythene bags. By keeping the moisture content below 10%, the feeds could be stored for a period of six months.

Using these feeds several experiments were conducted in which over 1,50,000 postlarvae of *Penaeus indicus* were stocked and reared in 24' dia. pools. Among the feeds tested, the feed PLF – 3 consisting of mantis shrimp 20%, prawn waste 20%, groundnut oil cake 30%, fish meal 10% and cassava 20% with a protein content of 36.8% gave the best performance in terms of growth and survival. The postlarvae were reared using this feed from PL_5 to PL_{20} with a survival rate of 90.3% and the larvae had grown from an initial average length of 6.0 mm to a final average length of 18.0 mm. Feeding was done at the rate of 100% of the body weight for the first two days and it was gradually brought down to 10% of the body weight finally. The cost of preparation of the feed was approximately Rs. 2/– per kilogram. The details of the experiments conducted and the results obtained using this feed are illustrated in the posters.

RESULTS OF EXPERIMENTAL PRAWN HATCHERY UNIT AT GUJARAT FISHERIES AQUATIC SCIENCE RESEARCH INSTITUTE, OKHA-GUJARAT

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Gujarat State is having 0.376 million hectares of brackishwater area. Of the 132 centres covered during the survey conducted for the last six years to locate suitable sites for coastal farms, 20 sites comprising 2000 heatares have been suggested for establishing coastal aquaculture farm. Though juveniles of *Metapenaeus spp.* are available, juveniles of *Penaeus spp.* are very few. Therefore in collaboration with the Central Institute of Fisheries Education, Bombay, a Prawn Hatchery unit was set up in 1980, by selecting *P. merguiensis* for the experiments.

In 1980, nine sets of experiments were conducted but larvae could not be reared up to post larvae. Egg custard was used as feed in the zoea stages. In 1981, monoculture of *Chaetoceros sp.* was developed and the zoea were found accepting this food very well. In the winter, with the water temperature, between 20° C to 25° C a culture media of 250 litres produced 3.5 lakhs cells/ml of *Chaetoceros sp.* within eight days.

In 1981, 4 sets of experiments were conducted. In the first experiment the mortality rate was found very high, but in the subsequent experiments the survival rate was found to be gradually increasing, results reaching 24%. Lack of sufficient quantity of live food and irregular supply of electric current were the main reasons for low survival rate. Having improved the technique and got sufficient quantity of live food viz. *Chaetoceros sp.* and local *Artemia salina,* the experiment conducted have resulted a survival rate of 30% during 1982. O

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